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## **Level I Energy and Water Survey, ERDC-CERL, Champaign, IL**

James P. Miller, David M. Underwood, Laura E. Curvey,  
Paul Loechl, and William T. Brown, III

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## Abstract

This project conducted an energy and water survey at the U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL, to identify energy and water inefficiencies and waste, and to propose energy and water-related projects that would enable the installation to better meet mandated energy and water reduction requirements. The survey included a Level I energy and water optimization assessment study, which reviewed the Main Complex and other buildings within the secured perimeter. The leased AT&T facility was not included in the study since ERDC-CERL intends to vacate the AT&T facility within the next 2 years. Also, the EFOB-L facilities on the north edge of the ERDC-CERL property were not included in the study since these facilities currently receive very minimal electrical support from the Main Complex.

The study identified nine economically viable energy conservation measures (ECMs) that, if implemented, would substantially reduce ERDC-CERL's annual energy consumption. These ECMs are presented in three groups according to the size of the required investment for each ECM. The study also identified four economically viable ("low-cost") water conservation measures (WCMs) that, if implemented, would reduce ERDC-CERL's annual water use by up to 207 kgal/yr.

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# Executive Summary

## Background and objectives

In fiscal year 2014 (FY14), the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL, initiated and funded an Energy and Water Survey with the following objectives:

- Use Corps of Engineers expertise to identify and propose projects to eliminate critical energy and water inefficiencies at ERDC-CERL.
- Organize survey results so that they can be easily entered into the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) Compliance Tracking System, which tracks progress toward meeting Section 432 of the Energy Independence and Security Act (EISA) of 2007 for Federal facility energy and water management and benchmarking. The EISA Section 432 Compliance Tracking System (CTS) tracks agency performance of energy and water evaluations, project implementation and follow-up measures, and annual building benchmarking requirements.
- Share good ideas and lessons learned among installations' energy teams and USACE districts to develop and successfully implement energy projects.
- Provide cost effective, best fit energy and mission solutions.

An Energy and Water Team performed a Level I survey during FY 2014. The scope of the Level I survey included a review of administrative areas, laboratories and warehouses and an analysis of their building envelopes, heating, ventilating, and air-conditioning (HVAC) systems, lighting systems, and water systems. Subject matter experts' (SMEs) evaluations were combined with findings from the Facility Energy Decision System (FEDS) modeling tool to develop and analyze ECMs. Water conservation measures (WCMs) were developed by an ERDC water systems expert.

## Project team

The study was managed and conducted by a team of ERDC-CERL energy and water SMEs. The Energy and Water Team provided expertise in mechanical systems, control systems, building envelopes and water systems.

ERDC-CERL personnel also collected input data to populate a FEDS model that was used to develop and analyze candidate ECMs.

## **Approach**

### **General**

The energy portion of this study was conducted using an energy assessment protocol developed by ERDC-CERL in combination with a FEDS analysis. This process has been used to conduct Energy Engineering Assessment Program (EEAP) studies for numerous Continental United States (CONUS) and Outside Continental United States (OCONUS) Army installations; it combines a “ground level” survey of existing systems with a “higher level” model-based assessment of the installation based on data gathered from a small number of buildings deemed to be representative of groups of buildings having similar occupancy, construction type, vintage, etc.

A similar “ground level” survey was conducted to identify and develop WCMs. FEDS was not used to develop WCMs, however, since FEDS does not address water conservation issues.

### **Objective of the Energy and Water Survey**

The objective of this energy and water survey was to identify projects with the potential to reduce ERDC-CERL’s energy and water usage and operational costs, to satisfy the energy and water survey and reporting requirements of EISA 2007, Section 432, and to enhance ERDC-CERL’s mission sustainability.

## **Progress toward Sustainability Metrics**

ECMs and WCMs described in this audit report have the potential to contribute toward ERDC-CERL’s energy intensity (MMBTU/KSF) reduction, water intensity (gallons/square feet) reduction, Scope 1 and 2 greenhouse gases reduction (MTCO<sub>2</sub>e), and renewable energy consumption. Table ES-1-1 summarizes the energy and water consumption and Greenhouse Gas (GHG) emissions for ERDC-CERL for FY08 and FY13 and projections for FY15.

Table ES-1-1. Energy, water consumption and GHG emissions for ERDC-CERL for FY08 and FY13.

Type	Units	Goal Subject or Goal Excluded	FY08		FY13		FY15	
			Qty	GHG (MTCO <sub>2</sub> e)	Qty	GHG (MTCO <sub>2</sub> e)	Qty	GHG (MTCO <sub>2</sub> e)
Fuel Oil #2	MMBtu	Subject	163.80	12	105.00	8	105.00	8
Electricity	MMBtu	Subject	12,177	2,982	13,005	3,044	11,335	2,653
	MMBtu	Excluded	7	2	133	31	133	31
	Electricity Subtotal		12,184	2,984	13,138		11,468	2,684
Natural gas	MMBtu	Subject	14,634	777	13,584	721	8,813	468
	MMBtu	Excluded	117	12	75	8	75	8
	Natural Gas Subtotal		14,751	789	13,659	729	8,888	476
Total Building-related energy (MMBTU)			27,099		26,902		20,461	
Energy Intensity (MMBTU / ft²)			166.63		165.42		125.81	
Vehicle fuel and refrigerants				70		41		41
Total GHG (MTCO <sub>2</sub> e)				3,855		3,853		3,209
Potable water (gallon)			2,801,250		3,415,768		3,208,668	
Water intensity (gal / ft²)			16.20		19.76		18.56	
Note 1: Projected FY15 values assume execution of all Low, Moderate and Significant Cost ECMs/WCMs documented in this report.								
Note 2: Energy intensity based on ERDC-CERL's Goal Subject area (Energy) of 162,627 ft²								
Note 3: Water intensity based on ERDC-CERL's Goal Subject area (Water) of 172,871 ft²								

## Energy Intensity

Energy intensity refers to the amount of building energy consumed per unit area (e.g., natural gas, fuel oil, and electricity) in buildings subject to the FEMP energy reduction goals (goal subject). The energy intensity goal is a 30% reduction from the FY03 base year by FY15. Based on ERDC-CERL's current goal subject building area of 162.627 KSF and an FY03 to FY15 energy intensity reduction target of 49.99 MMBTU/KSF, a reduction of 48.78 MMBTU/KSF below the FY13 energy intensity is required. This total required energy reduction of 7,933 MMBTUs from FY13 levels can be partially met through investments in all of the low, moderate, and significant cost ECMs described as economically viable in this report (Tables ES-1-2 and ES-1-3). Unfortunately, the estimated energy reduction of 6,421 MMBTU due to these ECMs falls somewhat short (1,492 MMBTU) of the reductions necessary to satisfy the FY15 target.

## **Greenhouse Gases**

Greenhouse gas (GHG) emissions result from both goal subject and goal excluded building energy consumption, as well as petroleum consumption related to non-tactical vehicle fleet (NTV) operations. Building-related energy consumption represents 98.9% of ERDC-CERL's GHG emissions. The GHG reduction metric is a 23% reduction in emissions from the FY08 base year by FY20. This represents a target reduction amount of 887 MTCO<sub>2e</sub> by FY20. To meet this reduction target, an additional reduction amount of 885 MTCO<sub>2e</sub> is required based on consumption at the end of FY13. Investments in all viable ECMs described in this report (Table ES-1-2 and ES3) are estimated to result in GHG reductions of 644 MTCO<sub>2e</sub>. These reductions could help ERDC-CERL achieve a substantial part of its FY20 GHG reduction goal.

## **Water Intensity**

Water intensity refers to the amount of metered potable water consumed per unit area in and around all buildings and structures on site. The water intensity goal is a 26% reduction from the FY07 base year by FY20. Based on ERDC-CERL's current square footage of 172,871 ft<sup>2</sup>, the FY08 water intensity was 16.20 gal/ft<sup>2</sup>. To meet the water intensity reduction target by FY20 would require a reduction of 4.21 gal/ft<sup>2</sup>. Unfortunately, between FY08 and FY13, ERDC-CERL's water intensity increased to 19.76 gal/ft<sup>2</sup>. As a result, to meet the FY20 target, a 39% reduction (7.77 gal/ft<sup>2</sup>) from current usage levels is required. Implementation of the WCMs described in this report (Tables ES-1-2 and ES-1-3) is expected to result in 207.1 kgal of annual water savings for a water intensity reduction of 1.2 gal/ft<sup>2</sup>. Additional water intensity reductions of 6.57 gal/ft<sup>2</sup> will be needed to meet the FY20 target.

## **Renewable Energy**

Each Federal agency is currently required to obtain at least 7.5% of their electricity demand from renewable energy sources (EPAct 2005). This may increase to 20% in the near future (President Obama Climate Action Plan, June 2013). USACE renewable energy consumption of 11.5% exceeds the current standard.

ERDC-CERL currently has no onsite renewable energy generation capabilities. Until recently there was a large open area north of the Main Complex

on which renewable energy technologies could have been installed. However newly constructed research projects have since taken up much of that available space.

Three renewable energy measures were evaluated as a part of this project but were not found to be economically viable. This was due to limited solar and wind resources for renewable energy projects and the relatively low electric and natural gas utility rates that ERDC-CERL currently pays.

To satisfy the Army's renewable energy requirements, ERDC-CERL might wish to consider purchasing Renewable Energy Credits (RECs). Ameren Illinois (ERDC-CERL's electric utility) sells blocks of RECs at \$10/1,000 kWh. EPACT 2005 requires Federal agencies to obtain 7.5% of their electrical consumption from renewable sources. At the 2013 consumption level this would require 243,751 kWh/yr of RECs at a cost of \$2,430 per year.

### **Other energy conservation initiatives**

ERDC-CERL and the University of Illinois, Urbana-Champaign (UIUC, the owner of the facilities) have been actively pursuing energy conservation measures (ECMs). Major improvements that have been completed or are in the planning stages include:

- installing programmable thermostats on split A/C systems, heat pumps, and packaged A/C units
- installing networked controls on fan coil units – Bldg 2
- windows replacement - Bldgs 1 and 2
- replace/upgrade boilers – Utilities Bldg.

These completed or planned projects were considered as part of this energy survey and are briefly discussed in Appendix J.

### **Results and recommendations**

This study identified nine ECMs and four WCMs that are economically viable as listed in Table ES-1-2. Economically viable ECMs were grouped into three different categories based on the size of the required investment as described in Chapters 2 through 4. Economically viable WCMs all fell within the category of "Low-Cost WCMs," i.e., those that should cost less than \$25,000 to implement and are described in Chapter 2. Table ES-1-3 summarizes the various energy and water reductions, utility cost savings, investment costs, and resulting simple payback of the various ECM/WCM

groupings. Six non-economical ECMs, some of which may become viable if utility rates increase, are discussed in Chapter 6.

If implemented, the economically viable ECMs/WCMs would reduce ERDC-CERL's annual energy use by up to 6,421 MMBTU/yr and water use by 207.1 kgal/yr. This amounts to 23.8% of ERDC-CERL'S FY13 energy use and 6.1% of FY13 water consumption.

The Federal High Performance Sustainable Building (HPSB) Checklist was applied to four buildings that are greater than 5,000 gross square feet and contain HVAC. This checklist outlining action items that are required to complete the online ENERGY STAR Portfolio Manager may be found in Appendix L.

Table ES-1-2. Summary of economically viable ECMs/WCMs.

ECM/ WCM	Title	Elec Energy Savings MMBtu	Thermal Energy Savings MMBtu	Total Energy Savings MMBtu	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	Savin gs-to- Invest ment Ratio (SIR)
<b>ECM Group 1 - Low-Cost ECMs (\$25k or Less)</b>									
BE-1	Install foundation (slab) insulation Bldgs 1 and 2	15	46	61		3,862	21,000	5.44	3.38
EL-1	Replace failed motors with premium efficiency motors vs. rewinding	12.5		12.5		214.4	739	3.45	4.12
HVAC-1	Insulate domestic hot water heaters	0	7.9	7.9		63.3	305	5.63	2.52
LI-1	Replace LED exit signs with electroluminescent exit signs	3	0	3		613	4,608	7.5	2.3
LI-2	Replace existing metal halide (MH) lighting systems	46.6	0	46.6		808.24	4,551	5.63	2.52
LI-3	Replace incandescent lights with (compact fluorescent lights) CFLs	8.2		8.2		279	197.5	0.71	9.71
WAT-1	Rebuild flush valves on restroom toilets				70.2	652	607	0.93	15.3
WAT-2	Upgrade/improve restroom faucet aerators		14.3	14.3	45.6	538	392	0.72	8.39
WAT-3	Rebuild urinal flushometers				21	195	2,024	10.37	1.36
WAT-4	Install water-saving kit on autoclave				70.3	683	3,909	5.7	2
	Group 1 Totals	85.3	68.2	153.5	207.1	\$7,908	\$38,333	4.85	
<b>ECM Group 2 - Moderate Cost ECMs (\$25k - \$150k)</b>									
HVAC-2	Convert constant volume pumping systems to variable volume	611.6	0	611.6		6,528	39,000	5.97	2.38
HVAC-3	Install fume hood controls	812	4,337.0	5,149.0		43,458	170,000	3.9	3.6
	Group 2 Totals	1,423.6	4,337.0	5,760.6	0	\$49,986	\$209,000	4.18	
<b>ECM Group 3 - Significant Cost ECMs (Above \$150k)</b>									
BE-2	Install/upgrade wall insulation, Bldgs 1 and 2	141	366	507		\$23,022	\$221,000	9.6	1.8
	Group 3 Totals	141	366	507	0	\$23,022	\$221,000	9.60	

Table ES-1-3. Summary of all economically viable ECMs/WCMs.

ECM/WCM Group	Elec Energy Savings MMBtu	Thermal Energy Savings MMBtu	Total Energy Savings (MMBtu)	Water Savin gs (kgal)	Cost Savings (\$K/yr)	Investment (\$)	Simple Payba ck (yrs)
ECM Group 1 - Low-Cost ECMs (\$25k or Less)	85.3	68.2	153.5	207.1	7,908	38,332	4.85
ECM Group 2 - Moderate Cost ECMs (\$25k - \$150k)	1,423.6	4,337.0	5,760.6	0.0	49,986.00	209,000	4.18
ECM Group 3 - Significant Cost ECMs (Above \$150k)	141.0	366.0	507.0	0.0	23,022.00	221,000	9.60
Totals	1,649.9	4,771.2	6,421.1	207.1	\$80,916	\$468,333	5.79

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## Preface

This study was conducted for the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. The technical monitor was Leslie M. Gioja, CEIT-DRE-N.

The work was managed and performed by the Energy Branch (CF-E) of the Facilities Division (CF) of ERDC-CERL. Appreciation is owed to numerous individuals at ERDC-CERL, including Les Gioja, Ron Huber, and Larry Kimball, CEIT-DRE-N, and to various employees of the University of Illinois Operations and Maintenance Division, including Corry Rosemont. At the time of publication, Mr. Andrew Nelson was Acting Chief, CEERD-CF-E; L. Michael Golish was Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CV-T was the Acting Technical Director. The Deputy Director of ERDC-CERL was Dr. Kirankumar V. Topudurti and the Director was Dr. Ilker R. Adiguzel.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

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## Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
British thermal units (Btu, International Table)	1,055.056	joules
MMBtu	0.293	MWh
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
Yards	0.9144	meters

# 1 Introduction

## 1.1 Background

The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) is one of seven ERDC laboratories and occupies a campus of facilities in Champaign, IL. The Main ERDC-CERL Complex facilities are leased from the University of Illinois (UIUC). The Main Complex comprises about 31 acres and has the following characteristics:

- Approximately 300 employees, about two-thirds government and one-third contractor employees.
- There is one central energy plant providing chilled water and heating hot water to Bldgs 1, 2, and 3.
- All utilities are publicly owned. Electrical energy (kWh) is provided by Direct Energy. Electric power distribution (kW) and natural gas service is provided by Ameren Illinois. The Illinois American Water Company provides water and sewer service is provided by the Urbana & Champaign Sanitary District. In general, onsite electrical, gas, and water/sewer infrastructure is owned and operated/maintained by UIUC.
- Electricity is relatively cheap and reliable.
- There is a centralized energy monitoring and control system (EMCS), that controls and/or monitors 16 of the 22 air handling units and 17 of 30 packaged units and split system units. Generally, the EMCS system is not connected to systems serving computer rooms or areas with fume hoods and/or very small packaged or split systems.
- Approximately 60% of the building controls are pneumatic, 25% electronic, and 15% direct digital control (DDC).
- ERDC-CERL's preferred BAS systems are based on LonWorks technology. Any future added or upgraded control devices/systems will be interfaced to ERDC-CERL's LonWorks Niagara Framework AX front-end. Existing LonWorks controls/devices at ERDC-CERL primarily include: Niagara Framework, Schneider Electric, TAC, Johnson Controls, Trane, and Continental Control Systems.
- Mechanical systems are scheduled to operate only during normally occupied hours. Air handling units are scheduled via the facility-wide

BAS system. Split systems and packaged units are generally scheduled by programmable thermostats.

- The predominant occupancy of floor space at ERDC-CERL is for office/administrative functions. The remainder of floor space is for laboratory space and logistics (storage) areas. This is significant from the standpoint that almost all of the space within the ERDC-CERL facilities require heating or cooling year around.
- Most heating systems use hot water from the central energy plant. A few smaller systems use electric heat pumps.
- The central energy plant chillers are water-cooled. A large number of air-cooled split system direct expansion (DX) units are located in various areas of the facility.
- Renewable energy opportunities (e.g., wind and solar hot water and photovoltaic [PV]) appear to be very limited.

## **1.2 Objectives**

The objective of this study was to identify energy and water inefficiencies and propose energy and water-related projects that could help ERDC-CERL meet energy and water reduction requirements mandated by EAct 2005; U.S. Energy Independence and Security Act of 2007 (EISA) 2007; and Executive Orders 13123, 13423 and 13514; and to help ERDC-CERL satisfy the energy and water survey and reporting requirements of EISA 2007 Section 432.

## **1.3 Energy and water survey project team**

ERDC-CERL managed the overall project and performed surveys of building envelopes, mechanical systems, lighting systems and water systems. ERDC-CERL personnel also collected input data for analysis using a Facility Energy Decision System (FEDS) model. FEDS is a building energy efficiency software tool developed by the Department of Energy that quickly and objectively identifies energy efficiency improvements that maximize life cycle savings.

## **1.4 Approach**

### **1.4.1 General**

This study was conducted using an energy assessment protocol developed by ERDC-CERL in combination with a FEDS model. The general energy assessment protocol process is:

1. Perform a Level 0 site survey to identify potential energy and water issues and to become familiar with the installation and its operations
2. Assemble a team of SMEs with expertise in technical areas relevant to facilities to be surveyed
3. Perform a technical assessment site survey (Level I) with SMEs to make building-specific energy and water conservation observations and gather data for installation-wide FEDS model development and calibration
4. Calibrate and optimize the FEDS model for the entire installation
5. Analyze findings and propose candidate energy and water projects.

### **1.4.2 Facilities surveyed**

Table 1-1 lists the buildings surveyed for specific energy conservation measures (ECMs) and water conservation measures (WCMs) and some pertinent information about those buildings.

### **1.4.3 Scope of the Energy and Water Survey**

The scope and depth of energy and water surveys differ in their objectives, methodologies, procedures, required instrumentation, and approximate duration. This project involved a Level I survey of administrative buildings, laboratories, and warehouses and an analysis of their building envelopes, HVAC systems, and lighting. It also included FEDS analysis and a Level I survey of installation water systems to identify cost effective ECMs and WCMs for application to the installation. The following sections describe these survey levels.

#### *1.4.3.1 Level I survey*

A Level I survey (qualitative analysis) is a preliminary energy and water survey consisting primarily of a walk-through review to view the conditions of existing equipment and facilities, to analyze and benchmark existing documents, and to verify consumption figures.

Table 1-1. List of buildings included in the energy and water survey.

Bldg No.	Footprint - Main Floor ft <sup>2</sup> *	Usage	Goal Subject Area (Gross Area All Floors Inside Face, ft <sup>2</sup> )	Goal Excluded Area (ft <sup>2</sup> )	Total Gross (for Water Intensity Calc, ft <sup>2</sup> )	Remarks
1	52,018	Admin/Lab (Including Bldg 1-2 Corridor and Uchi House)	54,201		54,201	
2	49,914	Admin/Lab (Including Bldg 2-3 Corridor)	57,477		57,477	
3	20,419	Admin	24,617		24,617	
4	14,018	Admin/Lab (Triaxial Earthquake and Shock Simulator [TESS], aka, the "Shaketable")	13,497		13,497	
5	10,074	Admin (AT&T Bldg.)	9,622		9,622	Not surveyed
6	876	Admin (Solar House)	811		811	
7	500	Storage (Chemicals)	442		442	
8	201	Storage (HazMat)	165		0	No water
9	4,432	Utilities Bldg.	4,104		4,104	
11	3,086	Warehouse (Pole Barn)	3,067		3,067	
12	1,480	Lab (Foam Panel Bldg.)	1,374		1,374	
13	2,517	Directorate of Public Works (DPW) Storage Bldg.	2,368		0	No water
14	297	Lab (Greenhouse)	0	286	286	
15	284	Storage	240		0	No water
16	311	Storage	264		0	No water
Totals	160,427		172,249	286	169,498	

\* Note that the "Bldg 10" designator is not used.

A typical Level I survey involves from 2 to 5 days of onsite activities, and identifies the bottom line dollar potential of energy conservation and process improvements. No engineering measurements using test instrumentation are made. If consumption figures are not available (e.g., due to a lack of metering), the Level I survey can be based on analyses and estimates by experienced surveyors. Level I surveys typically recommend that the installation perform some metering, which could be followed by a Level II survey to verify Level I survey assumptions and to refine ideas from the Level I screening process.

#### 1.4.3.2 Level II Survey (not conducted)

A Level II survey includes quantitative analysis geared toward funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. A Level II study typically takes five to 10 times the effort of a Level I survey, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. A Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of "ap-

propriation grade” energy and water system improvement projects for funding and implementation.

#### 1.4.4 Installation utilities information

##### 1.4.4.1 Historic utilities consumption

Figure 1-1 shows the historic electrical usage and cost from FY08 through FY13 and Figure 1-2 shows the historic gas usage and cost for ERDC-CERL’s Main Complex.

Figure 1-1. Historic electrical usage and cost, Main Complex.

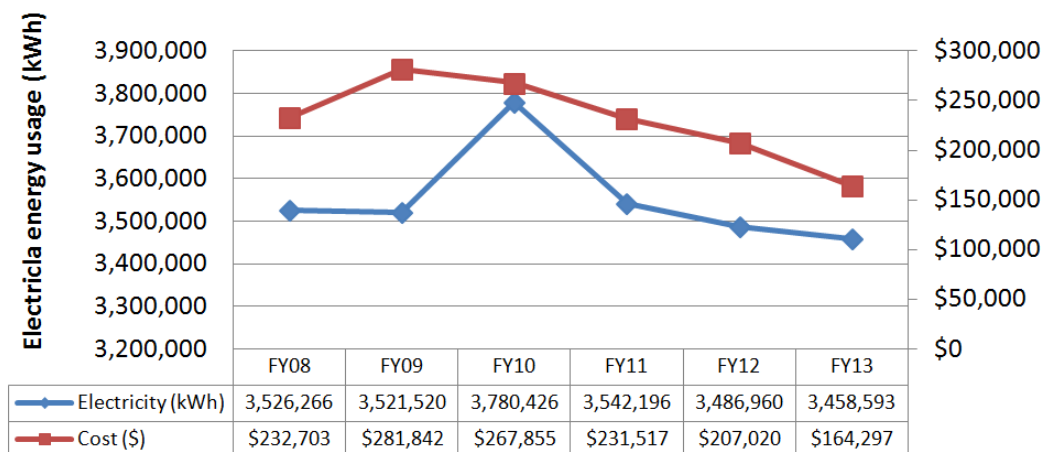
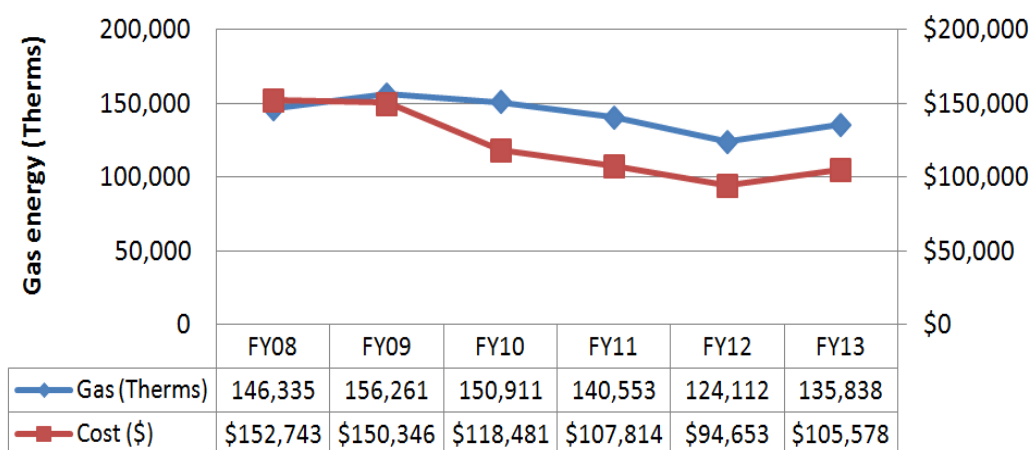


Figure 1-2. Historic natural gas usage and cost, Main Complex.



One can see a slight overall reduction in electrical usage from FY08 to FY13 and a significant reduction in electrical costs over that period. The cost reduction is primarily due to reduced electrical energy rates as a result of electrical deregulation. Natural gas usage also decreased slightly and there were significant natural gas cost reductions, mostly due to the reduced unit cost of natural gas.

Figure 1-3 shows the historic water usage (gallons) and cost from FY08 through FY13 and Figure 1-4 shows the historic sewer usage (100 ft<sup>3</sup>, CCF) and cost for ERDC-CERL's Main Complex.

Figure 1-3. Historic water usage and cost, Main Complex.

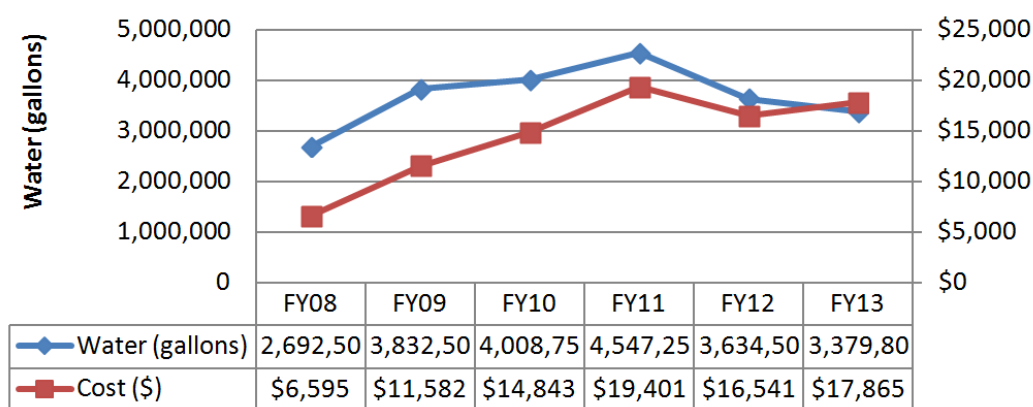
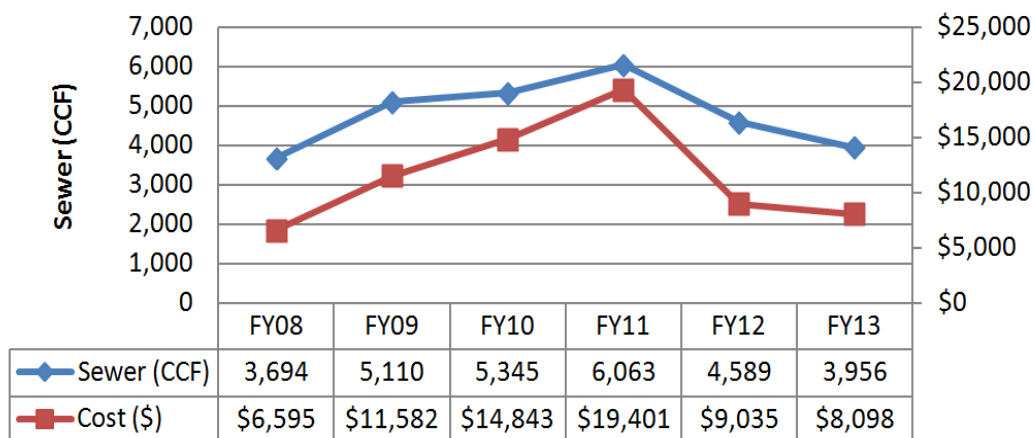


Figure 1-4. Historic sewer usage and cost, Main Complex.



#### 1.4.4.2 Referenced utility rates

Based on FY13 and FY14 utility billing statements, utility rates were determined for use in economic calculations (Table 1-2).

Unless noted otherwise, marginal electric energy and demand rates (shown in Table 1-2 with an asterisk [\*]) were used rather than a “blended” electrical energy rate because a marginal rate more properly addresses the economics for ECMs that could be expected to reduce both electrical energy consumption (kWh) and peak electrical demand (kW). Appendix A to this report discusses the method of calculating marginal electrical rates.

#### 1.4.5 Referenced climate data

The economic feasibility of various ECMs is highly dependent on local climate data. This project referenced climate data for the University of Illinois Willard Airport, which is the nearest World Meteorological Organization (WMO) weather station (WMO No. 725315) for which data is available. Since Willard Airport is within approximately 10 miles SSE of ERDC-CERL, Willard Airport weather data is probably a close enough approximation for purposes of this survey. University of Illinois Willard Airport climate data was obtained from the U.S. Air Force 14<sup>th</sup> Weather Squadron (<https://notus2.afccc.af.mil/>). Appendix B briefly discusses climate data for University of Illinois Willard Airport.

Table 1-2. Utility rates used in economic calculations.

Utility	Rates	Remarks
Natural Gas	\$8.01612/MMBtu	Ameren Illinois
Electrical Energy	\$0.036523/kWh	Marginal energy rate (Direct Energy)
Electrical Demand	\$5.7228/kW	Marginal demand (Ameren Illinois <sup>†</sup> )
Water and Sewer	\$9.287/kgal	Illinois American Water Company and Urbana & Champaign Sanitary District (combined rate)
<sup>†</sup> Ameren Illinois and Direct Energy Business		

#### 1.4.6 Results and findings

Chapters 2 through 4 present economically viable ECMs and WCMs. These chapters are organized by the estimated implementation costs for each ECM or WCM, as listed in Tables 1-3–1-5.

**Table 1-3. ECM Group 1: Low-Cost ECMs (\$25k or Less) (Chapter 2).**

ECM/ WCM	Title	Bldg. Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
BE-1	Install foundation (slab) insulation Bldgs 1 and 2	61		3,862	21,000	5.44	3.38
EL-1	Replace failed motors with premium efficiency motors vs. rewinding	12.5		214.4	739	3.45	4.12
HVAC-1	Insulate domestic hot water heaters	7.9		63.3	305	5.63	2.52
LI-1	Replace LED exit signs with electroluminescent exit signs	3		613	4,608	7.5	2.3
LI-2	Replace existing metal halide (MH) lighting systems	46.6		808.24	4,551	5.63	2.52
LI-3	Replace incandescent lights with CFLs	8.2		279	197.5	0.71	9.71
WAT-1	Rebuild flush valves on restroom toilets		70.2	652	607	0.93	15.3
WAT-2	Upgrade/improve restroom faucet aerators	14.3	45.6	538	392	0.72	8.39
WAT-3	Rebuild urinal flushometers		21	195	2,024	10.37	1.36
WAT-4	Install water-saving kit on autoclave		70.3	683	3,909	5.7	2
	Group 1 Totals	153.5	207.1	\$7,908	\$38,333	4.85	

**Table 1-4. ECM Group 2: Moderate Cost ECMs (\$25k to \$150k) (Chapter 3).**

ECM/ WCM	Title	Bldg. Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
HVAC-2	Convert constant volume pumping systems to variable volume	611.6		6,528	39,000	5.97	2.38
HVAC-3	Install fume hood controls	5,149.0		43,458	170,000	3.9	3.6
	Group 2 Totals	5,760.6	0	\$49,986	\$209,000	4.18	

**Table 1-5. ECM Group 3: Significant Cost ECMs (Above \$150k) (Chapter 4).**

ECM/ WCM	Title	Bldg. Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
BE-2	Install/upgrade wall insulation, Bldgs 1 and 2	507		\$23,022	\$221,000	9.6	1.8
	Group 3 Totals	507		\$23,022	\$221,000	9.6	

For purposes of this survey, projects were determined to be economically viable if they demonstrated an estimated simple payback of 10 yrs or less and a savings-to-investment (SIR) ratio greater than 1.0.

One ECM (discussed briefly in Chapter 5) was recommended for a Level II survey. Six ECMs were analyzed and determined to be economically non-viable. Table 1-6 lists these ECMs, which are also briefly described in Chapter 6.

Conclusions and recommendations are presented in Chapter 8.

## 1.5 Scope

This Level I Energy and Water Survey focused on the ERDC-CERL Complex facilities that are leased from UIUC. One smaller facility, which is leased from a private entity, was not included in this survey since ERDC-CERL plans to move out of this facility in less than 10 years, which is that estimated simple payback time considered economically viable for this work.

## 1.6 Mode of technology transfer

The results of this work will be presented to the ERDC-CERL DPW for consideration for implementation. It is anticipated that the results of this work will contribute to an enhanced awareness within ERDC, the U.S. Army Corps of Engineers and its districts, and other Army organizations of opportunities to improve the overall energy efficiency of Army installations.

Table 1-6. ECMs that are not economically viable (Chapter 6).

ECM/ WCM	Title	Bldg. Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
HVAC-5	Upgrade fan coil units in Bldg 1 to LonWorks controls	167.5	0	1,374	42,000	30.6	0.6
HVAC-6	Replace central plant chillers	995	0	11,000	239,000	21.5	0.77
LI-4	Upgrade existing 2x4-ft fluorescent light fixtures	45	0	706	8,497	12.04	1.18
REN-1	Install a small scale wind turbine	325	0	3,479	591,000	170	0.08
REN-2	Install photovoltaics	283	0	3,034	315,000	104	0.14
REN-3	Install a small scale wind turbine	9.9	0	79	6,000	76	0.19
	Non-Viable Group Totals	830.4	0	8,672	962,497	110.9	

## 2 ECM Group 1 – Low-Cost ECMs (\$25k or Less)

### 2.1 ECM BE-1: Install foundation (slab) insulation, Bldgs 1 and 2

Table 2-1. Potential savings, required investment, and simple payback associated with installing foundation (slab) insulation in Bldgs 1 and 2.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
15	46	61	\$3,862	\$21K	5.44	3.38

#### 2.1.1 Existing conditions

The buildings at ERDC-CERL do not have foundation insulation. Currently, the installation of foundation insulation is a standard practice and is typically economically viable. Buildings with foundation insulation have smaller heating and cooling loads than buildings without foundation insulation. Foundation insulation installation should be done to the extent possible where buildings do not abut concrete sidewalks and/or driveways.

#### 2.1.2 Solution

Add insulation to the perimeter of Bldgs 1 and 2. The insulation should cover the building perimeter into the ground to the same depth as the existing foundation. In the case of a foundation wall, the perimeter insulation should be applied to a depth of about 2 to 3 ft, where heat loss is most significant.

Appendix C includes a detailed discussion of ECM BE-1.

### 2.2 ECM EL-1: Replace failed motors with premium efficiency motors vs. rewinding

Table 2-2. Potential savings, required investment, and simple payback associated with replacing failed motors with premium efficiency motors (vs. rewinding).

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
12.5		12.5	214.4	739	3.45	4.12

### 2.2.1 Existing conditions

Electric motors are used in buildings to move hot and chilled water, and to force air through Air Handling Units (AHUs). Although most motors on pumps and AHUs at ERDC-CERL are relatively high efficiency, it is anticipated that there at least a few standard efficiency motors are used in older AHUs. Using premium efficiency motors can save electrical usage over time.

### 2.2.2 Solution

The solution is to replace existing standard efficiency electric motors with higher efficiency motors. Modern premium efficiency motors have nameplate efficiencies in the range of 90 to 95%. Typically the payback for outright replacement of functional standard efficiency motors with premium efficiency motors is not economically viable. Nevertheless, it is usually cost effective to replace failed motors with new premium efficiency motors rather than rewinding the failed motors. While it is possible to increase the efficiency of a motor by a rewind, typically the efficiency of a rewind motor can be as much as 20% less efficient than the original motor (Lecture course AGSM325 TAMU, Gregory L. Stark).

Appendix C provides a detailed discussion of ECM EL-1.

## 2.3 ECM HVAC-1: Insulate domestic hot water heaters

Table 2-3. Potential savings, required investment, and simple payback associated with insulating domestic hot water heaters.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
0	7.9	7.9	63.3	305	5.63	2.52

### 2.3.1 Existing conditions/problems

The domestic hot water heaters in Bldgs 1 and 2 at CERL are not insulated. As a result, heating energy is being lost to the surroundings.

### 2.3.2 Solution

Insulate the domestic hot water heaters.

Appendix C includes a detailed discussion of ECM HVAC-1.

## 2.4 ECM LI-1: Replace LED exit signs with electroluminescent exit signs

Table 2-4. Potential savings, required investment, and simple payback associated with replacing LED exit signs with electroluminescent exit signs.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
3	0	3	613*	4,608	7.5	2.3
* Includes \$582/yr of maintenance savings						

### 2.4.1 Existing conditions

All exit signs at ERDC-CERL were found to be backlit by LED technology. Exit signs are never turned off, so even the smallest decrease in sign wattage due to lamp retrofit will frequently be cost effective. Consequently, although LEDs are energy efficient, alternatives to LED exit lighting technologies can provide additional energy savings.

### 2.4.2 Solution

Electroluminescent exit signs use only 0.35 watts. Therefore, it is cost effective to retrofit all exit signs with this technology as it uses one-fifth of the energy of current LED technologies.

Appendix C includes a detailed discussion of ECM LI-1.

## 2.5 ECM LI-2: Replace existing MH lighting systems

Table 2-5. Potential savings, required investment, and simple payback associated with replacing existing MH lighting systems.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
46.6	0	46.6	808.24	4,551	5.63	2.52

### 2.5.1 Existing condition

The Utilities Bldg., Warehouse Bldg and Bldg 2 Hi-Bay areas use 400W MH high intensity discharge (HID) lighting fixtures. There are a total of 17 such units. More energy efficient options are available.

## 2.5.2 Solution

Replace existing 400W MH lighting fixtures with more efficient fluorescent fixtures with occupancy sensors and program start ballasts to save significant energy while increasing lighting system performance.

Appendix C provides a detailed discussion of ECM LI-2.

## 2.6 ECM LI-3: Replace incandescent lights with CFLs

Table 2-6. Potential savings, required investment, and simple payback associated with replacing incandescent lights with CFLs.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
8.2		8.2	279	197.50	0.71	9.71
*Based on replacing 50 60-watt incandescent bulbs operating 10-40 hours per year. Includes \$33.50/yr of maintenance savings						

### 2.6.1 Existing conditions

There are a few remaining incandescent lights used in various locations around the laboratory. For example, there are a few recessed can fixtures with 75W flood lights and a number of desk lamps using incandescent lights. Incandescent lights are extremely inefficient, producing very few lumens per watt consumed. In addition, they become hot and produce excess heat in the building and they burn out quickly, requiring them to be replaced often. While most incandescent lamps have been replaced at ERDC-CERL, a small number of them still exist in various buildings on site.

### 2.6.2 Solution

Replace all remaining incandescent lights with CFLs. CFLs use 65–80% less energy than incandescent lamps while maintaining the same light output (Table C-12). Moreover, these lamps last 7 to 10 times longer, reducing the need for maintenance labor and replacement lamps. Lastly, CFLs are now designed to fit incandescent bulb sockets; replacement is an easy switch of lamps instead of a complicated luminaire retrofit. In certain situations, CFLs are not an adequate substitute for incandescent bulbs; such as when light quality and historic appearance are important, as well as when having a highly dimmable fixture is desirable. In dimming applications, care should be taken to use a CFL that is designed for dimming.

Also, the dimming switch must be matched to work properly with a dimmable CFL. ERDC-CERL should consider stocking a small number of CFL bulbs and making these available to employees as a replacement for existing incandescent bulbs in desk lamps.

Appendix C provides a detailed discussion of ECM LI-3.

## 2.7 WCM WAT-1: Rebuild flush valves on restroom toilets

Table 2-7. Potential savings, required investment, and simple payback associated with rebuilding flush valves on restroom toilets.

Water Savings (kgal)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
70.2	652	607	0.93	15.3

### 2.7.1 Existing conditions

ERDC-CERL restroom facilities were audited to identify water conservation opportunities (WCMS). Duration-of-flush measurements to determine actual flush volumes were made on 12 of 24 toilets surveyed at ERDC-CERL buildings within the gated perimeter. A number of toilets were found with extended flushes, which wastes water. Extended flushes may be due to a variety of causes:

- The pressure supplied to the toilets and urinals may be so low that the flush valve closes more slowly than normal.
- Flush valve/toilet combinations may be mismatched.
- Flush valve retrofits may be improperly adjusted.
- Flush valve bypass orifices may be clogged or deformed.

### 2.7.2 Solution

Based on these observations, the flushometers should be examined in Bldgs 1, 2, and 3, which have a total of 19 toilets. If necessary, rebuilding flush valves includes unclogging orifices and adjusting flushometers to their rated flushing capacity.

Appendix C includes a detailed discussion of ECM WAT-1.

## 2.8 WCM WAT-2: Upgrade/improve restroom faucet aerators

Table 2-8. Potential savings, required investment, and simple payback associated with upgrading/improving restroom faucet aerators.

Water Savings (kgal)	Thermal Energy Savings (MMBtu)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
45.6	14.3	538	392	0.72	8.39

### 2.8.1 Existing conditions

Fifteen of 24 restroom faucets in six buildings were sampled and audited throughout the ERDC-CERL facility. These restroom faucets were rated between 2.2 and 1.5 gpm. The overall average rating was 1.65 gpm, but the overall average measured flow was 1.45 gpm. Seventy-nine percent (79%) of the measured faucet flow rates performed below rated capacity, 16% performed at capacity, and 4% had flow rates well above rated capacity, sometimes up to twice the rated capacity.

### 2.8.2 Solution

Regardless of their relative performance, all of these restroom faucets should be retrofitted with premium efficiency 0.5 gpm aerators. Where hand cleaning is the primary end-use, low flow aerators make cost effective sense.

Appendix C includes a detailed discussion of WCM WAT-2.

## 2.9 WCM WAT-3: Rebuild urinal flushometers

Table 2-9. Potential savings, required investment, and simple payback associated with rebuilding urinal flushometers.

Water Savings (kgal)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
21	195	2,024	10.37	1.36

### 2.9.1 Existing conditions

Five of 10 available urinals were assessed in the six buildings visited. The rated capacity of each one was 1.0 gpf. The average flush of the 1.0 gpf urinals, based on flush times, was 1.3 gpf. Extended flushing is likely due to similar issues mentioned above for toilet flush valves with low water pressure.

### 2.9.2 Solution

Rebuild the urinal flush valves.

Appendix C includes a detailed discussion of WCM WAT-3.

## 2.10 WCM WAT-4: Install recirculation system on autoclave

Table 2-10. Potential savings, required investment, and simple payback associated with the installation of a recirculation system on the autoclave system.

Water Savings (kgal)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
70.3	682.83	3,909	5.7	2.0

### 2.10.1 Existing conditions

The highest individual water demand in Bldg 1 comes from Rm 1035, which has an autoclave that serves several labs. This unit is run approximately twice daily, requiring 318 gal/day or 82.7 kgal/year, costing \$803.14 annually in water and sewer charges.

### 2.10.2 Solution

Install a recirculation system on the autoclave solution. Some recirculating systems can reduce water consumption of some sterilizers by up to 85%.

Appendix C includes a detailed discussion of WCM WAT-4.

### 3 ECM Group 2 – Moderate Cost ECMs (\$25k - \$150k)

#### 3.1 ECM HVAC-2: Convert constant volume pumping systems to variable volume

Table 3-1. Potential savings, required investment, and simple payback associated with the conversion of constant volume pumping systems to variable volume.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
611.6		611.6	\$6,528	\$39,000	5.97	2.38

##### 3.1.1 Existing conditions

There are currently large numbers of AHUs, fan coil units, reheat coils, and other terminal units that receive hot water and chilled water from the central utilities plant. The central plant supplies hot and chilled water to the ERDC-CERL Complex 24/7/365. Each of the main buildings has hot and chilled water distribution pumps that operate continuously at constant flow, even during periods when there is little or no heating or cooling load at the AHUs. When there is a reduced heating or cooling load, 3-way valves at each air handling unit divert the supply water through bypass piping directly to the return piping. This wastes considerable pumping energy and, in the case of the chilled water system, it adds energy (heat) to the chilled water loop, which needs to be removed by the chillers.

##### 3.1.2 Solution

Install variable frequency drives (VFDs) on the existing hot and chilled water distribution pumps to supply only as much hot water or chilled water to the buildings as the AHUs and other heating/cooling loads require.

Note that before implementation, this project should be coordinated with UIUC to make sure that it does not conflict with planned utility system upgrades.

Appendix D includes a detailed discussion of ECM HVAC-2.

### 3.2 ECM HVAC-3: Install fume hood controls

Table 3-2. Potential savings, required investment, and simple payback associated with the installation of fume hood controls.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
812	4,337.0	5,149.0	\$43,458	\$170K	3.9	3.6

#### 3.2.1 Existing conditions

ERDC-CERL has a total of 22 laboratory fume hoods, all located in Bldg 1. Most (19) of these units are located in the west side of the building, while the rest (3) are on the east side. All of the hoods appear to be constant volume (CV), operating in two modes: ON or OFF. All of the hoods have sashes and ON/OFF buttons. The newer models have controls that shut down the fan when the sash is completely closed. One fume hood seems to be nonoperational (and appears to be used for storage). Four of the units are biological fume hoods, which were not considered in this analysis.

#### 3.2.2 Solution

It is proposed that ERDC-CERL use a technique implemented by the University of Texas at Austin (UTA), which converts a CV fume hood to variable air volume (VAV). The technique uses an air valve to allow more or less air to be exhausted based on a sensor that:

- monitors if the sash is above or below a specified height (two-stage monitoring system), or alternatively
- continuously monitors the sash position (continuous monitoring system).

In either case a controller modulates the flow rate depending on sash position.

Appendix D includes a detailed discussion of ECM HVAC-3.

## 4 ECM Group 3 – Significant Cost ECMs (Above \$150k)

### 4.1 ECM BE-2: Install/upgrade wall insulation, Bldgs 1 and 2

Table 4-1. Potential savings, required investment, and simple payback associated with the installation/upgrade of wall insulation in Bldgs 1 and 2.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
141	366	507	\$23,022	\$221k	9.6	1.8

#### 4.1.1 Existing conditions

Bldgs 1 and 2 were constructed in 1969 with concrete block and brick exterior walls, and have not been subsequently insulated. Poorly insulated walls allow for high thermal losses, forcing heating and cooling systems to work harder and/or leaving the occupants uncomfortable.

#### 4.1.2 Solution

FEDS recommends installation of insulation with an R-value of 12.4 on the interior surface of the walls. However, given all of the objects that would have to be removed to do this, installation of External Insulation Finishing System (EIFS) might be a better option. EIFS can be made to look like most any surface such as the brick at ERDC-CERL. The cost for EIFS is estimated to be about \$10/ft<sup>2</sup>, or \$221k for Bldgs 1 and 2 resulting in a simple payback of 9.6 years.

Appendix E provides a detailed discussion of ECM BE-2.

## 5 ECM Group 4 – ECMs Recommended for Level II Analysis

### 5.1 ECM HVAC-4: Shut down central plant boilers during the cooling season

Table 5-1. Potential savings, required investment, and simple payback associated with the shutdown of central plant boilers during the cooling season.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
0	3,090	3,090	24,700	26,000	1.1	13.5

#### 5.1.1 Existing conditions

Currently, the central plant boilers in the Utilities Bldg operate year around. This is a questionable practice during the summer cooling season when there should be little or no heating load. There may be a number of locations that, for one reason or another, have a small reheat load. Unfortunately, it is likely that nobody really knows exactly what those heating loads might be or how large they are. If these possible reheat loads were identified and measured, there might be more economical ways of meeting these requirements than operating the central plant boilers all year long.

#### 5.1.2 Solution

It is recommended that a Level II investigation be performed to determine the exact locations and magnitudes of summer heating loads to determine if these loads are valid and/or if they can be handled in a more economical and energy efficient manner. A simple way to perform this investigation would be to merely turn off the central plant boilers for a week during the cooling season and see what impact this has on conditions in Bldgs 1, 2, and 3. Where there might be a possibility of an adverse impact (such as subcooling of office spaces or conference rooms or high humidity conditions in a copier room), coordinate with ERDC-CERL's DPW and UIUC Facilities & Services (F&S) to identify areas of concern and instrument them with temperature/humidity data loggers to measure and record the actual conditions in these areas during the period of the test. Appendix F provides a detailed discussion of ECM HVAC-4.

## 6 ECM Group 5 – Not Economically Viable ECMs

### 6.1 ECM HVAC-5: Upgrade fan coil units in Bldg 1 to LonWorks controls

Table 6-1. Potential savings, required investment, and simple payback associated with the upgrade of fan coil units in Bldg 1 to LonWorks controls.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
11.5	156	167.5	1,374	42,000	30.6	0.54

#### 6.1.1 Existing conditions

The existing controls for the 28 fan coil units (FCUs) in Bldg 1 are simple thermostats with a temperature setting and five modes (Off, Auto, Low, Medium, and High). Users typically do not turn the units off, even when they are gone for extended periods of time such as vacations or travel duty. Most offices have occupancy sensors that control lighting.

#### 6.1.2 Solution

Install LON-based networked thermostats in conjunction with occupancy sensors. Coordinate occupancy status with the FCU thermostat's temperature setpoint. This was done in Bldg 2 and has been successful in saving energy.

Appendix G provides a detailed discussion of ECM HVAC-5.

### 6.2 ECM HVAC-6: Replace central plant chillers

Table 6-2. Potential savings, required investment, and simple payback associated with the replacement of central plant chillers.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
995	0	995	11,100	239,000	21.5	0.77

### 6.2.1 Existing conditions

Bldgs 1, 2, and 3 are served by two 170-ton electric chillers (York Codepack rotary screw, model YSDBCA50CFAS, manufactured 1993) capable of a total cooling capacity of 340 tons based on 10 °F differential using R-22 refrigerant. The Utility Bldg has space for an additional chiller.

Based on the chillers' type and age, their energy use is estimated at 1 kW/ton.\* A thermal storage tank capable of storing 300 ton-hours of cooling capacity was added to the system and one of the chillers was modified to deliver low temperature glycol to the thermal storage tank. The chillers and the thermal storage tank share a common primary loop in the Utility Bldg. Two pumps circulate water through the chillers and around the primary loop.

### 6.2.2 Solution

Replace the existing chillers with more efficient models. Modern chillers are much more efficient. Several manufacturers now offer magnetic bearing chillers with Integrated Part Load Values (IPLVs) as low as 0.29 kW/ton. One drawback would be the loss of the thermal storage system resulting in a higher demand charge.

Appendix G provides a detailed discussion of ECM HVAC-6.

## 6.3 ECM LI-4: Upgrade existing 2x4-ft fluorescent light fixtures

Table 6-3. Potential savings, required investment, and simple payback associated with the upgrade of existing 2x4-ft fluorescent light fixtures.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
45	0	45	\$706	\$8,497	12.04	1.18
Note: Numbers posted above reflect upgrade of 100 fixtures						

### 6.3.1 Existing condition

Many private offices, cubicle spaces, conference rooms, and corridors are lighted by 2-lamp T-8 fluorescent fixtures have not been upgraded for

\* Gary Hamilton, Engineered Systems, July 2014, page 32.



#### **6.4.1 Existing conditions**

CERL currently has no renewable energy generation capabilities. Until recently there was a large open area north of the Main Complex on which renewables could have been installed. However, several recently installed research projects have since taken up much of that available space.

#### **6.4.2 Solution**

Install a small scale wind turbine, photovoltaics, and/or solar hot water generator.

#### **6.4.3 Savings, investment and payback**

A small scale wind turbine system comprised of four Gala Wind 133 turbines capable of producing 11 kW each was analyzed. A PV system capable of producing 70 kW was also evaluated as well as an 11,000 BTU/hr solar hot water system. A software tool developed by National Renewable Energy Laboratory (NREL), System Advisory Model (SAM) (<https://sam.nrel.gov/>) was used to analyze these systems at the ERDC-CERL location. Table 6-4 lists the projected savings, investments and paybacks for these renewable projects. Unfortunately, ERDC-CERL has very limited resources for renewable energy projects. Moreover, these projects do not sufficiently favorable payback (less than 10 years) to be recommended for implementation.

## **7 General Observations and Recommendations**

Some recommendations for energy and water savings are not designated as ECMs/WCMs in this report because their nature of those recommendations does not easily convert to discrete projects. Nevertheless, they are briefly described here and in more detail in Appendix H (Lighting Systems) and Appendix I (Irrigation Guidance).

### **7.1 Lighting system observations and recommendations**

#### **7.1.1 Improve lighting when performing spot replacement**

When performing spot replacements of lamps, ballasts, and fixtures that have reached “end-of-life” or “in-service failure,” take the opportunity to upgrade the lighting technology and delamp overlit areas as part of regular lighting maintenance procedures.

#### **7.1.2 Influence human behavior**

In individual offices and laboratory spaces, educate and motivate occupants to turn off lighting when not needed.

In “non-owned” spaces (including copy rooms, break rooms, conference rooms, and restrooms), consider using occupancy sensors to turn off lights when not needed.

#### **7.1.3 Use low-ballast factor (BF) ballasts when delamping is not possible**

Carefully select lamp/ballast combinations in existing overlit areas where it is not feasible to delamp or remove unneeded lighting fixtures. This will reduce lighting levels and energy consumption.

#### **7.1.4 Eliminate parabolic louvered troffers**

Eliminate parabolic louvered troffer lighting fixtures in hallways and other non-computer areas. Do not accept new or retrofit projects with parabolic louvers (Figure 7-1).

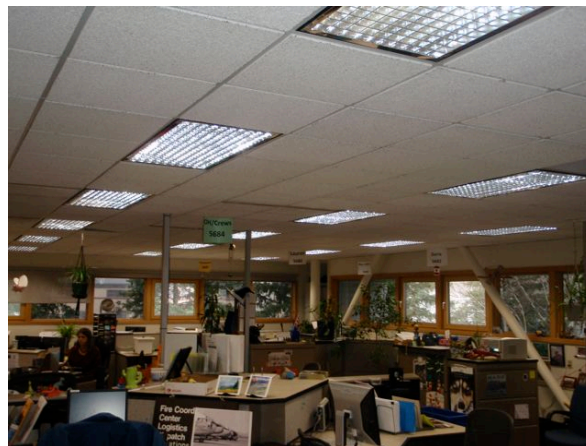
Figure 7-1. Parabolic louvered troffer.



#### 7.1.5 Eliminate paracube louvers

Replace paracube louvered fixtures (Figure 7-2) with large scale, clear prismatic lenses in conjunction with delamping. Large scale, clear prismatic lenses look much more aesthetically attractive than typical clear small scale prismatic lenses.

Figure 7-2. Paracube louvered troffers.



### **7.1.6 Eliminate white lenses**

White lenses typically block about 30% of light produced, compared to only about 10% for clear prismatic or ribbed lenses. Therefore, white lenses should be replaced when fixtures are delamped or when lower BF fixtures are added.

### **7.1.7 Minimize lamp and ballast types**

When possible, replace seldom-used lamp and ballast types with the predominant, high performance F32T8s or F17T8 lamps with extra efficient ballasts to reduce maintenance and inventory costs.

## **7.2 Irrigation observations and recommendations**

Landscape irrigation is frequently an overlooked use of water and often represents one of the biggest water demands on Federal facilities. Appendix I contains a spreadsheet that details many of the Federal policies and standards that all Federal facilities should reference when they actively irrigate their facilities. ERDC-CERL does not have established irrigation systems surrounding the facilities. However, spot irrigation is performed regularly for various reasons, i.e., construction remediation, new landscaping, and dry weather. Little attention is paid to the irrigation practices as they are done on an as needed basis, but DPW personnel admitted that irrigation may be done throughout an entire day for several days on spot locations. This practice can add up to some extensive water waste.

The minimum demand in most facilities is normally during winter months when little or no irrigation is performed. During the months of December, 2013 and February 2014, the demand was 222 kgal/month. In June of 2014, this demand rose to 384 kgal/month, a 72% increase from regular indoor demand. Assuming that most of this water is not going to the sewer it is still a \$925/month jump from winter month demands. Since irrigation is informally performed and several outdoor spigots are used it is easy for waste to occur. Without metering, it is also difficult to determine where the outdoor use is most extensive besides construction sites.

The surrounding landscaping has evolved over the years with some input from local researchers. However, ERDC-CERL DPW has no formal landscaping plan to guide overall landscaping, or suggest optimal use of

drought resistance plants. A landscaping and irrigation policy should be written to guide and limit water use.

### **7.3 Building water use observations and recommendations**

Besides irrigation, other major water uses for administrative buildings are broken down into two main areas: cooling towers and public restrooms.

#### **7.3.1 Bldg 1: CERL Laboratories**

Most of the laboratory work requiring water is located in Bldg 1. Besides the autoclave there is a distilled water system that provides water to several labs. Other uses include some dishwashing and batch work on corrosion projects. Anecdotal data gathered from interviews with researchers indicates that the volume for the batch work is unlikely to exceed 2,000 gal/yr. The laboratory's dishwashing needs seem to be limited to no more than two cycles a month, which is relatively insignificant. Most of the water pumps associated with local research are closed loop and do not have large reservoir volumes to replace.

#### **7.3.2 Bldg 2: Highbay**

A water-cooled CSG Lawrence Hydraulic pump with a once-through system in the high bay of Bldg 2 is infrequently used. In the fall of 2014, it will be used 7-10 times for at least an hour for a planned research project. The radiator cooling unit on this pump requires 6,000 gal/hr. Because this system is used so infrequently, it may not be necessary to install a recirculation system. However if there are plans to use this hydraulic pump on any regular basis beyond the plans for the fall 2014 project, then a recirculation system should be considered.

The rest of the building water use is mainly through the restrooms and the cafeteria sink, and an ice machine. The ice machine produces ~180 lbs of ice (21.6 gal) per day or 7.9 kgal/yr. The unit is an air-cooled model, which is much more efficient than water-cooled models.

#### **7.3.3 Bldg 3**

Water uses in this building are mainly restroom related. The cooling tower is located next to Bldg 3. Over the past 3 years, the cooling tower has con-

sumed on average 110 kgal of water per year. This equates to about \$1,021.57 in water and sewer costs annually. ERDC-CERL does get sewer credit for flow factor adjustments on the cooling tower. For 2013, ERDC-CERL received \$203.69 credit.

#### **7.3.4 Other ERDC-CERL buildings**

Other ERDC-CERL buildings have no significant water use beyond restroom facilities, which were included in the above overall calculations.

## 8 Summary

### 8.1 Summary

This project conducted an energy and water survey at ERDC-CERL as part of the USACE initiative to audit each of its EISA Sec 432 covered facilities. These audits are intended to: (1) identify energy and water waste and inefficiencies and propose energy and water consumption reduction projects, and (2) evaluate buildings over 5,000 sq ft for conformance to the *Guiding Principles for Federal Leadership in High Performance Buildings*. This report describes ECMs and WCMs that would enable the installation to address energy reduction requirements mandated by EPAct 2005, EISA 2007, and Executive Orders 13123, 13423, and 13514, as well as to satisfy the requirement to report energy and water progress in CTS and Guiding Principles progress in ENERGY STAR Portfolio Manager. The survey was conducted by subject matter experts (SMEs) from ERDC-CERL's Energy Branch (CF-E).

The scope of the project included a Level I survey of administrative areas, laboratory spaces, and other facilities, and an analysis of their building envelopes, HVAC systems, and lighting systems and water systems.

The survey identified nine different ECMs and four WCMs that were considered to be economically viable. If implemented, these ECMs/WCMs would reduce ERDC-CERL's annual energy use by up to 6,421 MMBtu/yr and water use by 207 kgal/yr. This amounts to 23.8% of ERDC-CERL's FY13 energy use and 6.1% of FY13 water consumption. Economically viable ECMs/WCMs are presented in three categories based on the estimated size of the investment necessary to implement them.

Economic analysis of the ECMs and WCMs shows that, if implemented, these measures will allow ERDC-CERL to reduce its annual energy costs by approximately 22.5% or \$60.9k and its annual water/sewer costs by approximately 7% or \$1.9k. The capital investment required to accomplish these savings is approximately \$483.3k, indicating an average simple pay-back period of 5.38 yrs. HVAC systems-related measures contribute 62%, building envelopes contribute 33%, lighting systems contribute 2%, and water systems contribute 3% of the savings.

## 8.2 Recommendations

Although the Level I analyses of multiple complex systems conducted during this Energy and Water Survey is not meant to be precise, the quantity and quality of the identified systems improvements suggest that potential exists for significant savings. It is recommended that ERDC-CERL pursue these potential cost, energy, and water savings measures with an aggressive program of process optimization and system improvements.

### 8.2.1 ECM group 1 – Low-cost ECMs (\$25k or less)

It is recommended that the ECMs/WCMs in this group be funded internally and implemented quickly. These ECMs/WCMs require little investment, involve little or no design work, and are very low risk. The nine ECMs/WCMs in this group all have an investment of \$25k or less and simple paybacks ranging from 0.5 to 10.4 years. Together they will save \$8.5k/yr for an investment of \$38.3k, resulting in a simple payback of 4.5 years.

Table 8-1. Projected savings, required investments, and simple payback for low-cost ECMs (\$25k or less).

ECM /WCM	Title	Bldg Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
BE-1	Install foundation (slab) insulation Bldgs 1 and 2	61		3,862	21,000	5.44	3.38
EL-1	Replace failed motors with premium efficiency motors vs. rewinding	12.5		214.4	739	3.45	4.12
HVAC-1	Insulate domestic hot water heaters	7.9		63.3	305	5.63	2.52
LI-1	Replace LED exit signs with electroluminescent exit signs	3		613	4,608	7.58	2.3
LI-2	Replace existing MH lighting systems	46.6		808.24	4,551	5.63	2.52
LI-3	Replace incandescent lights with CFLs	8.2		279	197.5	0.71	9.71
WAT-1	Rebuild flush valves on restroom toilets		70.2	652	607	0.93	15.3
WAT-2	Upgrade/improve restroom faucet aerators	14.3	45.6	538	392	0.72	8.39
WAT-3	Rebuild urinal flushometers		21	195	2,024	10.37	1.36
WAT-4	Install water-saving kit on autoclave		70.3	683	3,909	5.7	2
	Group 1 Totals	153.5	207.1	\$7,908	\$38,333	4.85	

### 8.2.2 ECM Group 2 - Moderate Cost ECMs (\$25k - \$150k)

It is recommended that the ECMs in this group be pursued as quickly as possible. These ECMs require a moderate investment. The two ECMs in Group 2 have investments ranging from \$39k to \$170k and simple pay-

backs ranging from 5.9 to 7.4 yrs. Together this group will save \$49.9k/yr for an investment of \$209k, resulting in a simple payback of 4.2 years.

Table 8-2. Projected savings, required investments, and simple payback for ECM/WCM HVAC-2-3.

ECM/ WCM	Title	Bldg Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
HVAC-2	Convert CV pumping systems to variable volume	611.6		6,528	39,000	5.97	2.38
HVAC-3	Install fume hood controls	5,149		43,458	170,000	3.9	3.6
	Group 2 Totals	611.6	0	\$49,986	\$209,000	4.18	

### 8.2.3 ECM Group 3 - Significant Cost ECMs (Above \$150k)

This FEDS-recommended ECM BE-2 requires a significant investment of \$221k (Table 8-3) and would have a simple payback of 9.6 years (Table 8-4).

Table 8-3. Investment required to implement FEDS-recommended ECM BE-2.

ECM /WCM	Title	Bldg Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
BE-2	Install/upgrade wall insulation, Bldgs 1 and 2	507		\$23,022	\$221,000	9.6	1.8
	Group 3 Totals	507	0	\$23,022	\$221,000	9.60	

Table 8-4. Projected savings, required investments, and simple payback for ECM Groups 1-3.

ECM Group	Bldg Energy Savings (MMBtu)	Water Savings (kgal)	Cost Savings (\$K/yr)	Investment (\$K)	Simple Payback (yrs)
ECM Group 1 - Low-Cost ECMs (\$25k or Less)	153.5	207.1	7,908.00	38,332.50	4.85
ECM Group 2 - Moderate Cost ECMs (\$25k - \$150k)	5,760.6	0.0	49,986.00	209,000.00	4.18
ECM Group 3 - Significant Cost ECMs (Above \$150k)	507.0	0.0	23,022.00	221,000.00	9.60
Totals	6,421.1	207.1	\$80,916.00	\$468,332.50	5.75

A number of ECMs/WCMs were evaluated and found to be economically non-viable at this time. In many cases, the relatively low-cost of energy and water at ERDC-CERL made it difficult to justify these ECMs/WCMs. However, should ERDC-CERL's utility rates rise significantly in the future, some of the ECMs/WCMs currently seen as non-viable may need to be re-considered.

"Non-viable" ECMs were documented in the report because they constitute some good ideas that should be considered for possible incorporation into the design of new construction projects or major renovations/upgrades/modernization of existing facilities. The economics of in-

stalling highly efficient systems tend to be quite good when performing a new construction project or a major renovation project because the only cost to consider when comparing the “most efficient” alternative against the “standard efficiency” alternative is the delta cost difference between the two alternatives. In such cases, many technologies that could never be justified as an energy or water conservation retrofit project will be found to have a very short payback and a good SIR.

### **8.3 Sustainability metrics progress**

This audit report identified and described potential ECMs and WCMs at ERDC-CERL that address energy intensity, water intensity, GHG emissions, and renewable energy consumption metrics. These metrics are part of USACE’s Campaign Plan and are tracked and reported by each District and laboratory.

The energy intensity goal is a 30% reduction from the FY03 base year by FY15. Based on FY13 energy consumption reported in CRAFT, ERDC-CERL needs to reduce its energy consumption by 7,933 MMBTUs to reach its energy intensity target of 116.64 MMBTU/KSF by FY15. This goal can be nearly met by investments in the low, moderate, and significant cost ECMs proposed in this report, which are estimated to reduce ERDC-CERL’s annual energy consumption by 6,421 MMBTU.

The water intensity goal is a 26% reduction from the FY07 base year by FY20. Based on ERDC-CERL’s current square footage of 172,871, the FY08 water intensity was 16.20 gal/ft<sup>2</sup>. Unfortunately, between FY08 and FY13, ERDC-CERL’s water intensity increased to 19.76 gal/ft<sup>2</sup>. As a result, to meet the FY20 target, a 39% reduction (7.77 gal/ft<sup>2</sup>) from current usage levels is required. Implementation of the WCMs described in this report is expected to result in 207.1 kgal of annual water savings for a water intensity reduction of only 1.2 gal/ft<sup>2</sup>. The WCMs documented in this report are relatively inexpensive and have a reasonable payback. To attempt to meet the FY20 target will require a number of rather aggressive measures to include cutting out or limiting spot irrigation and only allowing irrigation to establish xeriscaping. All fixtures would need to be upgraded to high efficiency fixtures, such as 1.28 gal/flush toilets and 0.5 gpm aerators and the water-saving kit for the autoclave would need to be installed.

The GHG reduction metric is a 23% reduction in emissions from the FY08 base year by FY20. This represents a target reduction amount of 887 MTCO<sub>2</sub>e from FY08 levels by FY20. To meet this reduction target, an additional reduction of 885 MTCO<sub>2</sub>e is required based on consumption at the end of FY13. Investments in all viable ECMs described in this report (see Tables ES-1-2 and ES-1-3) are estimated to result in GHG reductions of 644 MTCO<sub>2</sub>e, which will help ERDC-CERL achieve a substantial part of its FY20 GHG reduction goal.

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## Acronyms and Abbreviations

Term	Definition
AC	Air-Conditioning
ACE	Army Corps of Engineers
ADM	Administrative Building
ARI	Air-Conditioning and Refrigeration Institute
BAS	Building Automation System
BE	Building Envelope
BF	Ballast Factor
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CHW	Chilled Water
CONUS	Continental United States
COP	Coefficient of Performance
CRAFT	Corps of Engineers Reduced and Abridged FEMP Tool
CRT	Cathode Ray Tube
CTS	Compliance Tracking System
DDC	Direct Digital Control
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DPW	Directorate of Public Works
DX	Direct Expansion
ECM	Energy Conservation Measure
EEAP	Engineering Energy Analysis Program
EISA	U.S. Energy Independence and Security Act of 2007
EMCS	Energy Monitoring and Control System
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
FC	Footcandles
FEDS	Facility Energy Decision System
FEMP	Federal Energy Management Program
GE	General Electric
GHG	Greenhouse Gas
HID	High Intensity Discharge
hp	Horsepower
HPSB	High Performance Sustainable Building
HQ	Headquarters
HQDA	Headquarters, Department of the Army
HVAC	heating, ventilating, and air-conditioning
HW	Hot Water
IA	Information Assurance
ID	Identification

<b>Term</b>	<b>Definition</b>
IT	Information Technology
JCI	Johnson Controls, Inc.
KSF	thousand square feet
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
MMBTU	million BTU
MOU	Memorandum of Understanding
MZ	Multi-Zone
NETCOM	Network Command
NREL	National Renewable Energy Laboratory
NTV	Non-Tactical Vehicle
O&M	Operations and Maintenance
O&P	Overhead and Profit
OA	Outside AIR
OCONUS	Outside Continental United States
OMB	Office of Management and Budget
PIR	Passive Infrared
POA	Percentage of Outside Ai
POC	Point of Contact
PV	Photovoltaic
RS	Recommended Standard
RX	Retro-Commissioning
SF	Standard Form
SIR	Savings-to-Investment Ratio
TAB	Test/Adjust/Balance
TESS	Triaxial Earthquake and Shock Simulator
TR	Technical Report
U.S.	United States
UMCS	Utility Monitoring and Control System
USACE	U.S. Army Corps of Engineers
VAV	Variable Air Volume
VFD	Variable Frequency Drive
VIP	Very Important Person
WCM	Water Conservation Measure
WES	Waterways Experiment Station
WKS	Weeks of Summer Operation
WKW	Weeks of Winter Operation
WMO	World Meteorological Organization

## **Appendix A: Calculation of Marginal Electric Utility Rates**


For some purposes, one reasonable approach to determining electrical rates for economic analyses of ECMs is to calculate a “blended” electrical energy rate by dividing the bottom line amount of the electric utility’s invoice by the measured energy consumed for the invoiced period.

A more rigorous approach would respond to the fact that some ECMs, such as those that specify more efficient office lighting systems, can be expected to result in both decreased electrical energy consumption and reduced billable electrical demand. Other ECMs (such as those that specify controls to shut off lights or air handlers during non-occupied hours) may result in lowered electrical energy consumption, but may have little effect on the installation’s billable electric demand. As a result, when calculating economic impacts of various ECMs, it is appropriate to consider their impact on both electrical consumption and billable electric demand.

One could perform economic calculations with reference to the nominal energy rate (\$/kWh) and nominal demand rate (\$/kW) from a monthly electric utility billing statement. Unfortunately, nominal rates do not account for the various other cost items typically itemized on a utility bill such as those shown on the ERDC-CERL Main Complex’s electric utility invoice for April 2014 (Figure A-1).

Rather than depending on the nominal rates shown on an electric utility’s monthly invoice, a better approach is to calculate a “marginal” electrical energy rate (the cost of the “next” kWh of electrical energy consumption) and a “marginal” electrical demand rate (the cost of the “next” kW of billable electrical demand) to more accurately account for the fact that various types of ECMs will impact the site’s electric utility costs in different ways.

Figure A-1. Itemized charges for ERDC-CERL Main Complex's electrical utility invoice for April 2014.



**Direct Energy**  
Business

Account No: 1181932  
 Invoice Number: 141110020862121  
 Billing Date: April 21, 2014  
 Page 3

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**YOUR SERVICE CHARGES**

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2902 NEWMARK DR, CHAMPAIGN IL  
 EDC # 4230048174      Store Number :  
 PO #:

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**Direct Energy Business**  
**Electric Service**  
 Meter# 07191627

Service Period March 19, 2014 to April 16, 2014 Estimated-Total	204,273.9 kWh
Meter Multiplier of	
Service Period March 19, 2014 to April 16, 2014 Actual-Total	484.83 kW
Meter Multiplier of	

March 19, 2014 to April 16, 2014

Fixed Price - 204,273.9 kWh Total @ \$0.0314/kWh	\$6,414.20
Transmission Adjustment - 204,273.9 kWh Total @ \$0.000674/kWh	\$137.68
Current Actual Charges	\$6,551.88

**Average Usage:**

Average use per day for March 19, 2014 to April 16, 2014	7,295.496 kWh
Average use per day for March 19, 2013 to April 16, 2013	8,832.414 kWh

**Average Temperature:**

Average temperature for March 19, 2014 to April 16, 2014	47 degrees
Average temperature for March 19, 2013 to April 16, 2013	no temperature info.

**Ameren CILCO**  
**Electric Service**  
 Meter# 07191627

Service Period March 19, 2014 to April 16, 2014 Actual-Total	484.83 kW
Meter Multiplier of	
Service Period March 19, 2014 to April 16, 2014 Estimated-Total	204,273.9 kWh
Meter Multiplier of	

March 18, 2014 to April 16, 2014

CUSTOMER CHARGE	\$173.59
METER CHARGE	\$26.34
DISTRIBUTION DELIVERY KW CHG	\$2,180.15
TRANSFORMATION CHARGE	\$436.13
SINGLE BILL OPTION CREDIT	-\$0.21
ELECTRIC ENVIRONMENTAL ADJ	\$201.07
RIDER EDR CHARGE	\$373.82
Ameren Electric Distribution Tax	\$345.35
Current Actual Charges	\$3,736.24

**Average Usage:**

Average use per day for March 19, 2014 to April 16, 2014	7,295.496 kWh
Average use per day for March 19, 2013 to April 16, 2013	8,832.414 kWh

In Figure A-1, the basic electrical energy rate is shown to be \$0.0314/kWh, the transmission adjustment rate is \$0.000674/kWh, and the demand rate is \$4.497/kW\* (based on the 2014 rate for distribution delivery charge for primary supply voltage provided by Ameren Illinois under rate sched-

\* AmerenIllinois. January 2014. Rate MAP-P - Modernization Action Plan - Pricing: Delivery Charges Information Sheet, <https://www.ameren.com/sites/aiu/Rates/Documents/aiifMAPP114.pdf>.

ule DS-3 in Rate Zone III). This invoice shows total electrical demand of 484.8 kW.

A simple way to calculate the marginal electrical energy rate and the marginal electrical demand rate is to create a spreadsheet that allocates cost for each line item to the energy charge or to the demand charge. Figure A-2 shows such a spreadsheet.

Figure A-2. Spreadsheet for calculation of ERDC-CERL Main Complex's marginal energy rate (\$/kWh) and marginal demand rate (\$/kW) for April 2014.

Line	Utility	Rate Type	Rate Zone	Description	Qty	Units	Rate	Energy Portion	Demand Portion	Total
1	Direct Energy Business	Fixed Price		Energy Charge	204,273.90	kWh @	\$0.0314	\$6,414.20		\$6,414.20
2	Direct Energy Business	Fixed Price		Transmission Adjustment	204,273.90	kWh @	\$0.000674	\$137.68		\$137.68
<b>Total Direct Energy Business Charges</b>								<b>\$6,551.88</b>	<b>\$0.00</b>	<b>\$6,551.88</b>
3	Ameren CILCO	DS-3 (General Delivery Service)	III	Customer Charge Secondary Meter Voltage (up to and including 600 volts)					\$173.59	\$173.59
4	Ameren CILCO	DS-3 (General Delivery Service)	III	Meter Charge Secondary Meter Voltage (up to and including 600 volts)					\$26.34	\$26.34
5	Ameren CILCO	DS-3 (General Delivery Service)	III	Distribution Delivery Demand Charge Primary Supply Voltage	484.80	kW @	\$4.497		\$2,180.15	\$2,180.15
6	Ameren CILCO	DS-3 (General Delivery Service)	III	Transformation Charge Based on highest demand in last 12 monthly periods	739.20	kW @	\$0.590		\$436.13	\$436.13
7	Ameren CILCO	DS-3 (General Delivery Service)	III	Single Bill Option Credit Miscellaneous Charge				-\$0.213		-\$0.21
8	Ameren CILCO	DS-3 (General Delivery Service)	III	Rider EEA Electric Environmental Adjustment Charges	204,273.90	kWh @	\$0.0009843	\$201.07		\$201.07
9	Ameren CILCO	DS-3 (General Delivery Service)	III	Rider EDR Energy Efficiency and Demand-Response Cost Recovery Charges	204,273.90	kWh @	\$0.00183	\$373.82		\$373.82
10	Ameren CILCO	DS-3 (General Delivery Service)	III	Ameren Electric Distribution Tax Cost Recovery	204,273.90	kWh @	\$0.0016906	\$345.35		\$345.35
<b>Total Ameren CILCO Charges</b>								<b>\$920.03</b>	<b>\$2,816.21</b>	<b>\$3,736.24</b>
11	<b>Current Month Energy Charges</b>							<b>\$7,471.91</b>	<b>\$2,816.21</b>	<b>\$10,288.12</b>
								<b>\$0.036578</b>	<b>\$5.81</b>	
								<b>\$/kWh</b>	<b>\$/kW</b>	

The process of determining the marginal electrical energy rate and the marginal demand rate is described as:

- Line 1 (Energy Charge) is attributable to electrical energy usage at a rate of \$0.0314/kWh. The resulting charge is 204,273.90 kWh x \$0.0314/kWh = \$6,414.20.
- Line 2 (Transmission Adjustment) is attributable to electrical energy usage at a rate of \$0.000674/kWh. The resulting charge is 204,273.90 kWh x \$0.000674/kWh = \$137.68.
- Lines 1 and 2 of the Energy Portion column are then subtotaled.
- Line 3 (Customer Charge) is a flat rate charge attributable to demand as provided by Ameren Illinois under rate schedule DS-3 in Rate Zone III, so only the Demand Portion column contributes to this charge.
- Line 4 (Meter Charge) is a flat rate charge attributable to demand as provided by Ameren Illinois under rate schedule DS-3 in Rate Zone III, so only the Demand Portion column contributes to this charge.
- Line 5 (Distribution Delivery Demand Charge) is a charge attributable to demand. The resulting charge is 484.8 kW x \$4.497/kW = \$2,180.15.

- Line 6 (Transformation Charge) is a charge attributable to demand based on the highest demand in the past 12 monthly billing periods, with a flat rate of \$0.59/kW as provided by Ameren Illinois under rate schedule DS-3 in Rate Zone III. The transformation charge of \$436.13 as listed on the bill results in the maximum demand during the last 12 monthly billing periods to be  $\$436.13 / (\$0.59/\text{kW}) = 739.20 \text{ kW}$ .
- Line 7 (Single Bill Option Credit) is a flat rate charge attributable to electrical energy usage as provided by Ameren Illinois under rate schedule DS-3 in Rate Zone III, so only the Energy Portion column contributes to this charge.
- Line 8 (Rider EEA) is an Electric Environmental Adjustment (EEA) charge attributable to electrical energy usage that varies monthly. During April 2014, the EEA charge was \$0.0009843/kWh (AmerenIllinois 2014a). The resulting charge is  $204,273.90 \text{ kWh} \times \$0.0009843/\text{kWh} = \$201.07$ .
- Line 9 (Rider EDR) is an energy efficiency and demand response cost recovery charge attributable to electrical energy usage that varies every June. During April 2014, the EDR charge was \$0.00183/kWh (AmerenIllinois 2014b). The resulting charge is  $204,273.90 \text{ kWh} \times \$0.00183/\text{kWh} = \$373.82$ .
- Line 10 (Electric Distribution Tax Cost Recovery) is a charge attributable to electrical energy usage as provided by Ameren Illinois under rate schedule DS-3 in Rate Zone III, which is listed as \$0.0016906/kWh (AmerenIllinois 2014c). The resulting charge is  $204,273.90 \text{ kWh} \times \$0.0016906/\text{kWh} = \$345.35$ .

Finally, the columns are subtotaled one more time. The marginal energy rate is calculated by dividing the \$7,472.12 Energy Portion subtotal by the kilowatt hours recorded for the month. The resulting marginal energy rate for April 2014 is:

$$\$7,472.12 / 204,273.90 \text{ kWh} = \$ 0.036579/\text{kWh} \text{ (April 2014)}$$

The marginal demand rate is calculated by dividing the \$2,816.28 Demand Portion subtotal by the 484.8 kW of demand. The resulting marginal demand rate for April 2014 is:

$$\$2,816.28 / 484.8 \text{ kW} = \$ 5.396617/\text{kW} \text{ (April 2014)}$$

For this analysis, similar calculations were performed for the other 17 months. The resulting monthly marginal energy rates and monthly marginal demand rates were averaged. For the 18-month period from January

2013 through June 2014, the average marginal energy rate for the Main Complex at ERDC-CERL was found to be \$0.036523/kWh and the marginal demand rate was \$5.7228/kW. These average marginal rates were used in all cost savings calculations except where noted otherwise.

## Appendix B: University of Illinois Willard Airport Climate Data

The local climate conditions in Champaign are characterized by hot, humid summers and cold winters. This study referenced long-term climatic data for the University of Illinois Willard Airport, which is the nearest World Meteorological Organization weather station to ERDC-CERL (WMO No. 725315) for which data is available. The charts shown in Figures B-1 to B-4 are based on weather observations recorded from 1973 through 2004 compiled by the U.S. Air Force 14th Weather Squadron.

The data in Figures B-1 to B-4 indicate that the Champaign, IL, climate has a significant cooling season with 1,189 cooling degree days (CDD, Base 65 °F), yet also has a very substantial heating season with 5,842 heating degree days (Base 65 °F).

The full set of University of Illinois Willard Airport climate data is available from the U.S. Air Force 14th Weather Squadron's website at:

<https://notus2.afccc.af.mil/>

Figure B-1. Annual summary of temperatures, Champaign, IL.

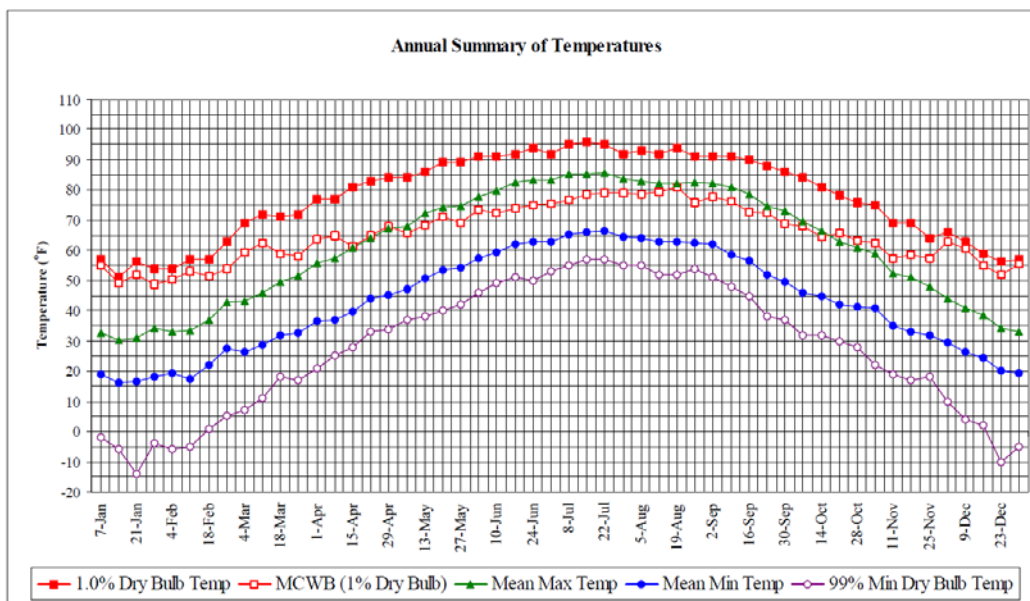


Figure B-2. Annual summary of temperatures, University of Illinois Willard Airport, WMO No. 725315.

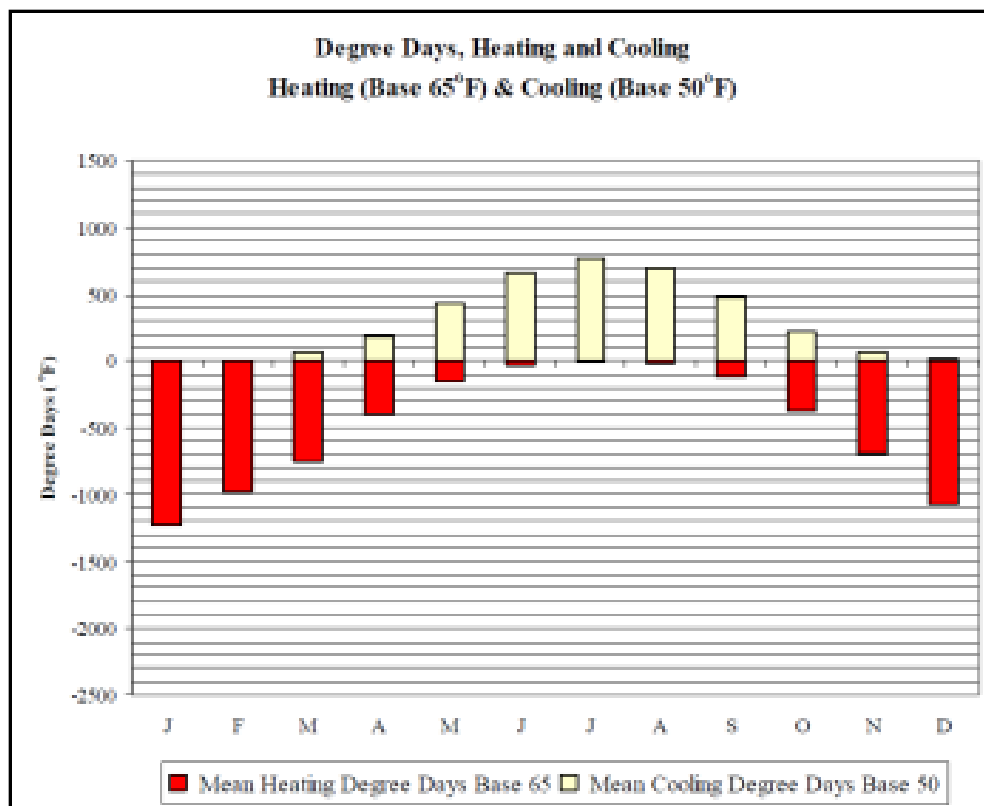
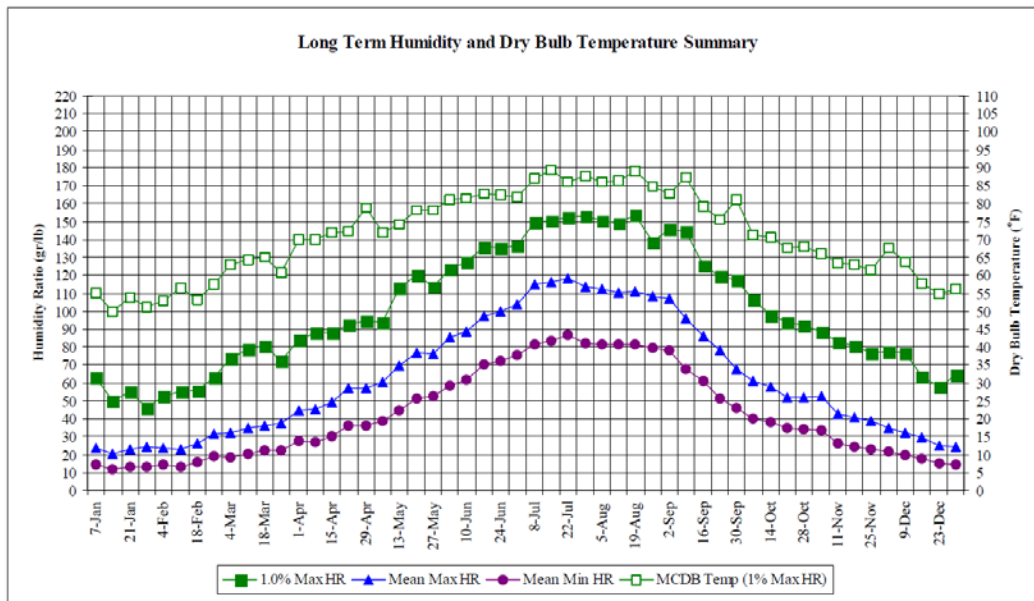


Figure B-3. Chart of heating and CDD, University of Illinois Willard Airport, WMO No. 725315.

	Mean Cooling		Mean Cooling		Mean Heating	
	Degree Days (°F)		Degree Days (°F)		Degree Days (°F)	
	Base 50		Base 65		Base 65	
JAN		4		0		1231
FEB		8		0		983
MAR		61		7		751
APR		187		31		401
MAY		437		114		158
JUN		660		253		36
JUL		773		332		11
AUG		700		269		23
SEP		485		147		111
OCT		214		33		366
NOV		57		3		691
DEC		10		0		1080
ANN		3596		1189		5842

Figure B-4. Chart of humidity ratio and dry bulb temperature, University of Illinois Willard Airport, WMO No. 725315.



## Appendix C: Detailed Discussion – Group 1 ECMs/WCMs

### C.1 ECM BE-1: Install foundation (slab) insulation, Bldgs 1 and 2

Table C-1. Projected savings, investments, and paybacks associated with the installation of foundation (slab) insulation in Bldgs 1 and 2.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
15	46	61	\$3,862	\$21k	5.44	3.38

#### C.1.1 Existing conditions

The buildings at ERDC-CERL do not have foundation insulation. Currently, the installation of foundation insulation is a standard practice and is typically economically viable. Buildings with foundation insulation have smaller heating and cooling loads than buildings without foundation insulation. Foundation insulation installation should be done to the extent possible where buildings do not abut concrete sidewalks and/or driveways.

#### C.1.2 Solution

Add insulation to the perimeter of Bldgs 1 and 2. The insulation should cover the building perimeter from the ground floor into the ground to the same depth as the existing foundation. In the case of a foundation wall, the perimeter insulation should be applied to a depth of about 2 to 3 ft, where heat loss is most significant. Savings

According to the FEDS model, adding insulation to Bldgs 1 and 2 would save 61 MMBtu/yr. Total monetary savings are \$3,862/yr.

There are no Operations and Maintenance (O&M) savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

#### C.1.3 Investment

FEDS estimates a total cost of \$21k. This may or may not be a reasonable cost estimate. Implementation of this ECM will be limited by the existence

of asphalt and concrete paving around a large portion of the buildings and may also be limited by the existing landscaping around the buildings.

#### **C.1.4 Payback**

Using the FEDS savings and cost estimates, the simple payback is 5.44 years. Based on an expected useful life of 30 years, the estimated SIR is 3.38.

## **C.2 ECM EL-1: Replace failed motors with premium efficiency motors vs. rewinding**

Table C-2. Projected savings, investments, and paybacks associated with replacing failed motors with premium efficiency motors (vs. rewinding).

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
12.5	0	12.5	214.4	739	3.45	4.12

### **C.2.1 Existing conditions**

Electric motors are used in buildings to move hot and chilled water, and to force air through AHUs. Although most motors on pumps and AHUs at ERDC-CERL are relatively high efficiency, it is anticipated that at least a few standard efficiency motors are used in older AHUs. Using premium efficiency motors can save electrical usage over time.

### **C.2.2 Solution**

The solution is to replace existing standard efficiency electric motors with higher efficiency motors. Modern premium efficiency motors have name-plate efficiencies in the range of 90 to 95%. Typically the payback for outright replacement of functional standard efficiency motors with premium efficiency motors is not economically viable. Nevertheless, it is usually more cost effective to replace failed motors with new premium efficiency motors rather than to rewind the failed motors. While it is possible to increase the efficiency of a motor by a rewind, typically a rewind motor can be as much as 20% less efficient than the original motor (Lecture course AGSM325 TAMU, Gregory L. Stark).

### C.2.3 Savings

Energy savings resulting from replacing standard efficiency electric motors with premium efficiency motors can be estimated as:

$$\text{Energy Savings} = \text{motor hp} \times \left( \frac{1}{E_{\text{old}}} - \frac{1}{E_{\text{new}}} \right) \times \text{hr/yr operation} \times 0.746 \text{ kW/hp} = \text{kWh/yr}$$

Additionally, for motors that run 24/7/365 electrical demand reductions can be calculated as:

$$\text{Demand Savings} = \text{motor hp} \times \left( \frac{1}{E_{\text{old}}} - \frac{1}{E_{\text{new}}} \right) \times 0.746 \text{ kW/hp} = \text{kW}$$

For motors that run 24/7/365 the annual electrical energy cost savings would be calculated as:

$$\text{Cost Savings} = \text{hp} \times \left( \frac{1}{E_{\text{old}}} - \frac{1}{E_{\text{new}}} \right) \times 8760 \times 0.746 \text{ kW/hp} \times \text{Energy Charge} = \$/\text{yr}$$

Also, for motors that run 24/7/365 the annual electrical demand cost savings would be calculated as:

$$\text{Demand Cost Savings} = \text{hp} \times \left( \frac{1}{E_{\text{old}}} - \frac{1}{E_{\text{new}}} \right) \times 0.746 \text{ kW/hp} \times \text{Demand Charge} \times 12$$

It is necessary to include the factor of 12 in the demand cost savings calculation since demand is a monthly line item on utility bills.

This analysis assumes that existing 5, 10, and 15 HP, 1800 RPM, standard efficiency motors are identified as possible replacement candidates. The data in Table C-3 assume that all of these motors operate 12 hrs per day, 5 days per week, and 52 weeks/yr (3,120 hrs/yr). The assumed energy rate is \$0.0365/kWh and the demand charge is \$5.7228/kW.

Table C-3. Cost and savings due to replacing existing standard efficiency motors with premium efficiency motors at 3,120 run hours per year.

Motor HP	Weekly Hrs of Operation	Old Motor Efficiency	New Motor Efficiency	New Motor Cost	Labor Cost	Energy Cost Savings (\$/yr)	Demand Reduction (\$/yr)	Savings (\$/yr)
5	60	82%	90%	619	124	46.07	27.77	73.84
10	60	88%	92%	979	140	42.00	25.31	67.31
15	60	90%	93%	1,230	175	45.70	27.54	73.25

The data in Table C-3 clearly indicate that it would be hard to justify replacing an existing standard efficiency motor that was only running 60 hours per week. Of the three motors listed in Table C-3, the most favorable motor (5 HP) would have a simple payback of almost 10 years and an SIR of 1.41 (assuming a useful life of 20 years). The other two motors will not pay back within a reasonable time frame.

The data in Table C-4 result from an identical analysis, except it was assumed that the motors that operate 24/7/365 were to be replaced.

Table C-4. Cost and savings due to replacing existing standard efficiency motors with premium efficiency motors at 8,760 run hours per year.

Motor HP	Weekly Hrs of Operation	Old Motor Efficiency	New Motor Efficiency	New Motor Cost	Labor Cost	Energy Cost Savings (\$/yr)	Demand Reduction (\$/yr)	Savings (\$/yr)
5	168	82%	90%	619	124	129.01	27.77	156.78
10	168	88%	92%	979	140	117.60	25.31	142.91
15	168	90%	93%	1,230	175	127.97	27.54	155.51

The data in Table C-5 show that it is much more economical to replace motors that operate 24/7/365.

Table C-5. Economics of replacing standard efficiency motors with premium efficiency motors (assuming 24/7/365 operation).

Motor HP	Simple Payback (yrs)	SIR
5	4.74	3.00
10	7.83	1.82
15	9.03	1.57

As seen in this discussion, the economics of replacing existing operational standard efficiency motors is highly dependent on a number of factors, including:

- annual hours of operation
- old motor efficiency
- new motor efficiency
- motor and labor costs
- marginal energy and demand rates.

As a practical matter, there are probably very few existing functional standard efficiency motors at ERDC-CERL for which outright replacement for energy conservation purposes is justified. However, when facing a decision to repair or replace a failed motor, the economics are quite different.

Table C-6 lists the cost premium between purchasing a new motor and rewinding an existing, failed motor. The data in Table C-7 indicate that, if the same motors analyzed in Table C-3 were assumed to operate 60 hours per week, it would be more economical to replace them with a higher efficiency motors than to repair them to “standard efficiency.”

Table C-6. Delta cost of a new motor vs. cost of rewinding an existing motor.

Motor Size (hp)	Delta Cost
25	\$488
20	\$425
15	\$335
10	\$260
7.5	\$212
5	\$144
3	\$115
1	\$93

Table C-7. Cost and savings due to replacing existing standard efficiency motors with premium efficiency motors at 3,120 run hours per year.

Motor HP	Weekly Hrs of Operation	Old Motor Efficiency	New Motor Efficiency	New Motor Cost Minus Rewind Cost	Delta Labor Cost	Savings (\$/yr)	Simple Payback (yrs)	SIR
5	60	82%	90%	144	0	73.84	0.92	15.47
10	60	88%	92%	260	0	67.31	1.82	7.81
15	60	90%	93%	335	0	73.25	2.15	6.60
Total				\$739		\$214.40	3.45	4.12

#### C.2.4 Investment

The cost of rewinding a failed motor usually runs in the range of 40 to 65% of the cost of a new motor. Table C-6 lists estimated delta costs for rewinding failed motors versus replacement with new premium efficiency motors of various sizes. Assuming replacement of a failed 5 HP, 10 HP and 15 HP motor with new premium efficiency motors rather than rewinding them,

the delta investment cost of replacement versus rewinding these failed motors would be \$739.

### C.2.5 Payback

The estimated simple payback for replacement of failed 5 HP, 10 HP, and 15 HP motors with new premium efficiency motors is 3.45 years with an SIR of 4.12 over the expected useful life of 20 years.

This issue was discussed with the UIUC electrical maintenance chief (Mr. Louis Hillyer, 217-714-2536) who is responsible for maintaining electric motors at ERDC-CERL. He said that most of the time they will replace burned out motors unless they are particularly large or of a unique design. It is recommended that ERDC-CERL's policy be that all burned out motors be replaced with premium efficiency motors except in very rare circumstances.

## C.3 ECM HVAC-1: Insulate domestic hot water heaters

Table C-8. Projected savings, investments, and paybacks associated with insulating domestic hot water heaters.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
0	7.9	7.9	63.3	305	5.63	2.52

### C.3.1 Existing conditions/problems

The domestic hot water heaters in Bldgs 1 and 2 at CERL are not insulated. As a result, heating energy is being lost to the surroundings.

### C.3.2 Solution

Insulate the domestic hot water heaters.

### C.3.3 Energy savings

According to FEDS calculations savings would be 79 therms/yr of natural gas, which equates to a cost savings of approximately \$63.32/yr.

### C.3.4 Investment

This measure would cost \$305.

### C.3.5 Payback

The simple payback would be 5.63 months and the SIR would be 2.52.

## C.4 ECM LI-1: Replace LED exit signs with electroluminescent exit signs

Table C-9. Projected savings, investments, and paybacks associated with replacing LED exit signs with electroluminescent exit signs.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
3	0	3	\$613*	\$4,608	7.5	2.3
*Includes \$582/yr of maintenance savings						

### C.4.1 Existing conditions

All exit signs at ERDC-CERL were found to be backlit by LED technology. Exit signs are never turned off, so even the smallest decrease in sign wattage due to lamp retrofit will frequently be cost effective. Consequently, although LEDs are energy efficient, alternatives to LED exit lighting technologies can provide additional energy savings.

### C.4.2 Solution

Electroluminescent exit signs use only 0.35 watts. Therefore, it is cost effective to retrofit all exit signs with this technology as it uses one-fifth of the energy of current LED technologies.

### C.4.3 Savings

FEDS calculates that replacing all of the exit signs will save 3 MMBtu/yr in electrical use, which results in a savings of \$31/yr.

Electroluminescent exit signs have a much longer lifetime than LEDs, incandescent bulbs, and fluorescent lamps. Therefore, the maintenance savings are significant at \$582/yr.

The total savings are estimated at \$613/yr.

### C.4.4 Investment

Installation of the new exit signs will cost \$4,608.

### C.4.5 Payback

With a total savings of \$613/yr, the simple payback would be 7.5 yrs.  
Based on a 25-yr useful life, the SIR is estimated to be 2.3.

## C.5 ECM LI-2: Replace existing MH lighting systems

Table C-10. Projected savings, investments, and paybacks associated with replacing existing MH lighting systems.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
46.6	0	46.6	808.24	4,551	5.63	2.52

### C.5.1 Existing condition

There are nine existing 400 MH HID light fixtures in the Utilities Bldg  
There are four MH fixtures in the Bldg 2 Hi-Bay area and four MH fixtures in the Warehouse for a total of 17 such fixtures. More energy efficient lighting options are available.

### C.5.2 Solution

Replacement of the existing MH fixtures with fluorescent fixtures designed for such applications would save significant energy while increasing lighting system performance. The existing 400W MH fixtures should be replaced one-for-one with either 4-lamp T5 54HO fixtures (216 watts per fixture) or 6-lamp T8 32W fixtures (218 watts per fixture). All fixtures should be specified with integral occupancy sensors to minimize ON time when there is little or no occupancy. Program start ballasts should also be specified for each fixture to maximize lamp life.

### C.5.3 Savings

The estimated savings resulting from implementing this measure are calculated as follows. Assuming that:

- to replace 17 existing fixtures:
  - Existing fixtures consume 455 watts (lamp plus ballast)
  - Operate 8 hrs per day, 260 days/yr (2,080 hrs/yr)
- and replacement fixtures:
  - consume 218 watts (lamps plus ballast)
  - operate 50% of the time of existing (1,040 hrs/yr)

$$\begin{aligned}\text{Annual Energy Cost Savings} &= 19 \times [(455 \text{ watts} \times 2080 \text{ hrs/yr}) - (218 \text{ watts} \times 1,040 \text{ hrs/yr})] \times \$0.0365/\text{kWh} = \$499.10/\text{yr} \\ \text{Annual Demand Cost Savings} &= 19 \times (0.455 - 0.218 \text{ kW of demand per month}) \times 12 \text{ months/yr} \times \$5.7228/\text{kW/month} = \$309.24/\text{yr} \\ \text{Total Annual Electrical Cost Savings} &= \$499.10 + \$309.24 = \$808.24/\text{yr}\end{aligned}$$

Therefore, total cost savings are estimated to be \$808.24/yr.

#### C.5.4 Investment

The estimated cost to implement this measure includes:

$$\begin{aligned}\text{Materials} &- 17 \text{ fixtures} @ 108.57 \text{ each} = \$1,845.69. \\ \text{Labor} &- 17 \text{ fixtures} @ 159.15 \text{ each} = \$2,705. \\ \text{Total investment cost} &\text{ would be } \$4,551.\end{aligned}$$

Note that the materials costs were from a vendor quote and the labor costs were estimated based on RS Means Electrical Cost Data 2012, but adjusted for 2 years of inflation.

#### C.5.5 Payback

The simple payback associated with this ECM would be 5.63 yrs.

$$\text{Simple Payback} = \text{Total Investment Cost} / \text{Annual Savings} = \$4,551 / (\$808.24/\text{yr}) = 5.63 \text{ yrs}$$

Assuming a useful lifetime of implementing this ECM of 20 years, the SIR would be 2.52:

$$\begin{aligned}\text{Lifetime Savings Total} &= \text{Annual Savings} \times \{[(1 + 3.5\%)^{20} - 1] / (3.5\% \times (1 + 3.5\%)^{20})\} = \$11,487 \\ \text{SIR} &= \text{Lifetime Savings} / \text{Total Investment Cost} = \$11,487 / \$4,551 = 2.52\end{aligned}$$

This analysis shows that this ECM would be economically feasible.

### C.6 ECM LI-3: Replace incandescent lights with CFLs

Table C-11. Projected savings, investments, and paybacks associated with replacing incandescent lights with CFLs.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
8.2		8.2	279	197.50	0.71	9.71
*Based on replacing 50 60-watt incandescent bulbs operating 1,040 hours per year. Includes \$33.50/yr of maintenance savings						

#### C.6.1 Existing conditions

There are a few remaining incandescent lights used in various locations around the laboratory. For example, there are a few recessed can fixtures

with 75W flood lights and a number of desk lamps using incandescent lights. Incandescent lights are extremely inefficient, producing very few lumens per watt consumed. In addition, they become hot and produce excess heat in the building and they burn out quickly, requiring them to be replaced often. While most incandescent lamps have been replaced at ERDC-CERL, a small number of them remain in use in various buildings on site.

### **C.6.2 Solution**

Replace all remaining incandescent lights with compact fluorescent lights (CFLs). CFLs use 65 to 80% less energy than incandescent lamps while maintaining the same light output (Table C-12). Moreover, these lamps last 7 to 10 times longer, reducing the need for maintenance labor and replacement lamps. Lastly, CFLs are now designed to fit incandescent bulb sockets; replacement is an easy switch of lamps instead of a complicated luminaire retrofit. In certain situations, CFLs are not an adequate substitute for incandescent bulbs; such as when light quality and historic appearance are important, and when a highly dimmable fixture is desirable. In dimming applications, care should be taken to use a CFL that is designed for dimming. Also, the dimming switch must be matched to work properly with a dimmable CFL. ERDC-CERL should consider stocking a small number of CFL bulbs and making these available to employees as a replacement for existing incandescent bulbs in desk lamps.

### **C.6.3 Savings**

Replacing a single 60W incandescent bulb with a 14W CFL would result in savings of 46 watts. Assuming operation of 4 hours per day, 5 days per week (a total of 1,040 hrs/yr), replacing a single 60W bulb would amount to annual energy savings of 47.8 kWh (0.163 MMBtu/yr). This results in electrical energy and demand cost savings of \$4.91/yr.

Added to this would be maintenance savings. Assuming that a 14W CFL costs about \$3.95 and lasts about 10,000 hrs, its annual replacement cost (assuming 1,040 hrs of use per year) would be \$0.41. By comparison, a 60W incandescent bulb that costs \$1.25 and has an expected life of 2,100 operating hours would have an annual replacement cost of \$1.08. As a result, the CFL operating roughly 1,040 hours per year would realize total savings of about \$5.58 per year.

### C.6.4 Investment

Replacing a single 60W incandescent bulb with a 14W CFL would cost about \$3.95.

### C.6.5 Payback

With a total savings of \$5.58/yr, the simple payback would be 0.71 yrs. Based on an expected useful life of 8 yrs, the SIR would be 9.71.

Table C-12. Retrofit options (replace incandescent lights with CFLs).

Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage
IN1: INC 40 CEIL	CF2: CFL 9 INTEGRAL UNIT ELC	40	9
IN23: INC 60 WALL	CF36: CFL 13 INTEGRAL UNIT ELC	60	13
IN32: INC 60 CAN	CF36: CFL 13 INTEGRAL UNIT ELC	60	13
IN5: INC 60 CEIL	CF36: CFL 13 INTEGRAL UNIT ELC	60	13

## C.7 WCM WAT-1: Rebuild flush valves on restroom toilets

Table C-13. Projected savings, investments, and paybacks associated with rebuilding flush valves on restroom toilets.

Water Savings (kgal/yr)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
70.2	\$651.93	607	0.93	15.3

### C.7.1 Existing conditions

ERDC-CERL restroom facilities were audited to identify water conservation opportunities (WCMS). Duration-of-flush measurements to determine actual flush volumes were made on 12 of 24 toilets surveyed at ERDC-CERL buildings within the gated perimeter. The exterior "AT&T" building was not surveyed due to future plans to bring all employees into the gated area. Correctly operating 1.6 gpm flushometer toilets should complete their flush cycle in approximately 5 seconds. Average flush time for 1.6 gpm-rated restroom toilets throughout ERDC-CERL was 5.4 seconds resulting in an average of 1.7 gal/flush, which is 6% above rated capacity. Three toilets of the 12 surveyed toilets demonstrated protracted flushes. One toilet was in Rm 1115 in Bldg 1, one was in Rm 2163 in Bldg 2 and the other was in Rm 3004 in Bldg 3. The toilets in Bldg 1 and 3 were in women's restrooms. In Bldg 2, a delayed flushing toilet was in the women's locker room. There were 21 tankless toilets all of which were sensor acti-

vated toilets. The remaining three were manually operated tank toilets, which were located in the Solar House, Shake Table Bldg., and the Warehouse.

Extended flushes may be due to a variety of causes:

- The pressure supplied to the toilets and urinals may be so low that the flush valve closes more slowly than normal.
- Flush valve/toilet combinations may be mismatched.
- Flush valve retrofits may be improperly adjusted.
- Flush valve bypass orifices may be clogged or deformed.

For larger installations, the combination of manual and sensor toilets observed among the buildings may indicate possible non-standard retrofit practices over the years that could lead to mis-pairing of retrofits. There is a common misconception that it is only necessary to change a toilet's flushometer to a more efficiently rated model to upgrade toilet efficiency from 3.6 gpf to 1.6 gpf. Unfortunately, some toilet designs require replacing the toilet bowl for the retrofitted 1.6 gpf flushometer to flush at its rated capacity. Thus when the flushometers are installed, their valves are set to flush for a particular toilet bowl. As a result, longer flushes may indicate that the flushometer and the toilet bowl are mismatched. Also, as noted, the building water pressure may be too low for the valve to close properly. For ERDC-CERL, the standard toilet design and valve type associated with the bowls generally seem to work according to rated capacity. Regarding water pressure, the measured water pressure for Bldgs 1, 2, and 3 were approximately 50 psi, which is sufficient to close toilet valves. Generally low water pressure is not uncommon at Federal facilities.

Nine of the 12 measured toilets operated at rated capacity. Their locations were within buildings that also had extended flushes. This may indicate that the building pressure is sufficient and the extended flushes are due to maladjusted valves or clogged orifices at those toilets.

### **C.7.2 Solution**

Based on these observations, the flushometers should be examined in Bldgs 1, 2, and 3, which have a total of 19 toilets. If necessary, rebuilding flush valves includes unclogging orifices and adjusting flushometers to their rated flushing capacity.

### C.7.3 Savings (per toilet)

This analysis uses the Bldg 1 estimated daily occupancy of 120 persons/day, and assumes six toilet uses per person per day as reference for consumption, and assumes that 50% of the occupants are women. Based on measurements above, the average savings per flush would be 1 gal. Women's restrooms typically experience more frequent use than men's restrooms. Since a woman is likely to use a toilet around three to four times per day (Vickers 2001), then 60 women are likely to use two toilets in Bldg 1 at least 180 times/day. With a rebuilt valve that performs at 1.6 gpf, then it is assumed that a rebuilt flush valve will save 90 gal/day in Rm 1115, the women's restroom. The combined cost of water and sewer at ERDC-CERL is \$9.287/kgal. Assuming the toilets are used weekdays only (260 days/yr), each rebuilt flush valve will save 23.4 kgal/yr and approximately \$217.31 of water/sewer savings per year:

$$\begin{aligned} \text{Lifetime Savings Total (per toilet)} &= \\ &(\text{Total Savings/yr}) * \{((1+3.5\%)^{20})-1\} / (3.5\% * (1+3.5\%)^{20}) \\ \text{Life cycle of the rebuild or project} &= 20 \\ \text{Lifetime Savings Total (per toilet)} &= \\ &(\$217.31) * \{((1+3.5\%)^{20})-1\} / (3.5\% * (1+3.5\%)^{20}) = \$3,088.50 \end{aligned}$$

Note that this calculation represents the life cycle cost savings (per toilet) over its expected useful life of 20 yrs. For three toilets, this would amount to savings of \$9,266.

### C.7.4 Investment

This cost analysis assumes that extended flushes are *not* due to low water pressure at each individual building. This analysis used 2013 RS Means Facilities Maintenance and Repair Cost Data adjusted to localized cost index using Champaign, IL data (Material-99.8%, Installation-106.8%, Total-102.9% of RS Means index). The costs reflect an overhead and profit requirement assumed by RS Means and does not directly reflect costs associated with work done by UIUC, which owns the facilities. If a proposed project requires additional labor beyond RS Means assumptions, it will be annotated to reflect the additional overhead and profit costs. Based on this analysis, the cost of maintenance and material to rebuild the flush valves would be \$202.38 per toilet:

$$\begin{aligned} \text{Total Investment per toilet} &= \text{Adjusted Labor} + \text{Material} + \text{O\&M Costs} \\ &= \$53.89 + \$88.71 + 59.78 = \$202.38 \end{aligned}$$

For three toilets, this cost would total \$607.

### C.7.5 Payback

The simple payback to rebuild the flush valves would be:

$$\$202.38 / \$217.31/\text{yr} = 0.93 \text{ yrs}$$

The SIR would be:

$$\text{SIR} = \text{Savings Total for three toilets} / \text{Investment Total for three toilets}$$

$$\text{SIR} = \$9,266 / \$607 = 15.3$$

### C.7.6 Applicable locations

This applies to a total of three toilets in Bldgs 1, 2, and 3.

## C.8 WCM WAT-2: Upgrade/improve restroom faucet aerators

Table C-14. Projected savings, investments, and paybacks associated with upgrading/improving restroom faucet aerators.

Savings (kgal)	Thermal Energy Savings (MMBtu)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
45.6	14.26	\$538	\$392	0.72	8.39

### C.8.1 Existing conditions

Faucets that were evaluated included restroom and kitchen sink faucets. Discussion with laboratory personnel mentioned that most of their sinks were used infrequently (possibly once or twice per week for filling some containers, but most commonly once a month for glassware cleaning). Most of the water used in the deskwork laboratory is small quantities of distilled water from a system in Rm 1016 or 1035. Twenty-four bathroom faucets were audited along with three kitchen faucets. No leaks were noted at any faucets, including utility and laboratory sinks.

Kitchen, utility, and laboratory faucets' primary end-use is volume availability for tasks such as filling containers. Therefore efficiency at these locations may not be in the best interest of the users. For purposes of efficiency, restroom faucets have the highest potential for actual cost effective savings.

Fifteen of 24 restroom faucets in six buildings were sampled and audited throughout the ERDC-CERL facility. These restroom faucets were rated between 2.2 and 1.5 gpm. The overall average rating was 1.65 gpm, but the overall average measured flow was 1.45 gpm. Seventy-nine percent (79%) of the measured faucet flow rates performed below rated capacity, 16%

performed at capacity, and 4% had flow rates well above rated capacity, sometimes up to twice the rated capacity.

### C.8.2 Solution

Regardless of their performance relative to their rating, all of these restroom faucets should be retrofitted with high efficiency 0.5 gpm aerators. Where hand cleaning is the primary end-use, low flow aerators make cost effective sense.

### C.8.3 Savings

Retrofitting the restroom faucets would yield an immediate water savings of 63% based on the average measured performance of existing faucets. Using Bldg 2 as an example, the average usage rate with 80 daily occupants and each occupant using restroom faucets three times per day at 15 seconds per use, this would amount to 60 minutes of faucet usage per day. This is then divided by 7 faucets within the building equaling 8.6 minutes per faucet per day. As the average existing faucet runs at 1.35 gpm, new 0.5 gpm aerators would reduce flows by 0.85 gpm on average. This would create a savings of 1.9 kgal of water per year per faucet and water/sewer savings of \$17.64/yr per faucet in Bldg 2, assuming usage only on weekdays (260 days/yr). As each building has different occupancy and demand, Bldg 2 has the median demand and occupancy, therefore the Bldg 2 usage rate and demand flow per faucet is extended as an average across all buildings to calculate overall savings.

Calculation of thermal energy savings assumed that each faucet use event results in a 30 °F temperature change during hand-washing based on setpoint temperatures for sensor faucets. It takes 1 BTU to raise the temperature of a pound of water by 1 °F and there are 8.34 pounds per gallon of water. Assuming a water heater efficiency of 80%, it would take 312.75 BTU to raise the temperature of 1 gallon of water 30 °F at the faucet. ERDC-CERL natural gas rates are \$0.801612/therm (100,000 BTU). With assumed consumption rates, each high efficiency aerator could save water heating energy requirements by 5.94 therms/faucet or \$4.76/yr, creating a total annual savings of \$22.40 per faucet.

$$\text{Lifetime Savings Total (per aerator)} = \frac{(\text{Total Savings/yr}) * \{((1+3.5\%)^7)-1\}}{(3.5\%*(1+3.5\%)^7)}$$

$$\begin{aligned} \text{Life cycle of the rebuild or project} &= 7 \\ \text{Lifetime Savings Total (per aerator)} &= \\ &(\$22.40) * \{((1+3.5\%)^7 - 1) / (3.5\% * (1+3.5\%)^7)\} = \$136.97 \end{aligned}$$

Total lifetime savings for 24 aerators would be \$3,287.18.

#### C.8.4 Investment

The 0.5 gpm aerators cost between \$1 and \$5 each and installation involves very little labor. Based on RS Means, the estimated investment cost per faucet would be:

$$\begin{aligned} \text{Total Investment} &= \text{Adjusted Labor} + \text{Material} + \text{In-house costs, i.e.,} \\ & \$9.87 + \$3.41 + \$3.04 = \$16.32 \end{aligned}$$

Total investment for 24 aerators would be \$391.68.

#### C.8.5 Payback

The simple payback would be:

$$\$16.32 / \$22.40/\text{yr} = 0.72 \text{ yrs}$$

Assuming a 7-yr useful life of a new aerator and assuming replacement of 24 aerators, the SIR would be:

$$\begin{aligned} \text{SIR} &= \text{Savings Total for 24 aerators} / \text{Investment Total for 24 aerators} \\ \text{SIR} &= \$3,287.18 / \$391.68 = 8.39 \end{aligned}$$

This project is very attractive economically.

### C.9 WCM WAT-3: Rebuild urinal flushometers

Table C-15. Projected savings, investments, and paybacks associated with rebuilding urinal flushometers.

Water Savings (kgal/yr)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
21	\$195	\$2,024	10.37	1.36

#### C.9.1 Existing conditions

Five of 10 available urinals were assessed in the six buildings visited. The rated capacity of each one was 1.0 gpf. The average flush of the 1.0 gpf urinals, based on flush times, was 1.3 gpf. Extended flushing is likely due to similar issues mentioned above for toilet flush valves with low water pressure.

### C.9.2 Solution

Rebuild the urinal flush valves.

### C.9.3 Savings

Using Bldg 2 as an example, savings calculations assume 80 daily occupants, 40 of whom are men. On average, men use the urinal twice a day; on that basis, three urinals average 27 uses per day. If the urinals are, on average, 0.3 gpf beyond their rating, rebuilding the flush valves could potentially save 8 gal/day or 2.1 kgal/yr per urinal.

$$\text{Annual Savings (per urinal)} = 2.1 \text{ kgal} * 9.71380 = \$19.50/\text{yr}$$

Assuming a 20-yr useful life of the rebuilt flushometer, the lifetime savings would be:

$$\text{Savings Total per urinal} = (\text{Total Savings/yr per urinal}) * \frac{((1+3.5\%)^{20} - 1)}{(3.5\% * (1+3.5\%)^{20})}$$

$$\text{Savings Total per urinal} = (\$19.50) * \frac{((1+3.5\%)^{20} - 1)}{(3.5\% * (1+3.5\%)^{20})} = \$277.14$$

This would result in water cost savings of \$19.50/yr/urinal or \$277.14 saved over the life of the rebuilt flushometer.

### C.9.4 Investment

Based on RS Means data, the investment cost to rebuild the flushometers would be:

$$\text{Investment (per urinal)} = \text{Adjusted Labor} + \text{Material} + \text{In-house costs} \\ \$53.89 + \$88.71 + \$59.78 = \$202.38$$

### C.9.5 Payback

The simple payback would be:

$$\$202.38 / \$19.50/\text{yr} = 10.37 \text{ yrs}$$

Assuming a 20-yr useful life of a rebuilt urinal flush valve and assuming rebuild of 10 valves, the SIR would be:

$$\begin{aligned} \text{SIR} &= \text{Savings Total for 10 urinals} / \text{Investment Total for 10 urinals} \\ \text{SIR} &= \text{Lifetime Savings Total for 10 urinals} / \text{Investment Total for 10 urinal flushometers} \\ \text{SIR} &= \$2771.40 / \$2,023.80 = 1.36 \end{aligned}$$

This project is justified economically.

## C.10 WCM WAT-4: Install water-saving kit on autoclave

Table C-16. Projected savings, investments, and paybacks associated with installing a water-saving kit on the autoclave system.

Water Savings (kgal)	Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
70.3	682.83	3,909	5.7	2.0

### C.10.1 Existing conditions

The highest individual water demand in Bldg 1 comes from Rm 1035, which has an autoclave that serves several labs. This unit is run approximately twice daily, requiring 318 gal/day or 82.7 kgal/yr, costing \$803.14 annually in water and sewer charges.

### C.10.2 Solution

Install a water-saving kit on the autoclave system. A growing number of water-saving kits that can be retrofitted to existing autoclaves is becoming available on the market. These kits are typically self-contained units for attachment to water and drain connections. Depending on the model, these kits can save between 68-92% of water consumption giving up to \$706.60 in annual savings (van Gelder, 2005).

### C.10.3 Savings

Assuming water consumption savings of up to 92%, the annual water/sewer cost savings would be approximately \$706.60.

$$\text{Annual Savings (per pump)} = 76.1 \text{ kgal} * \$9.287/\text{kgal} = \$706.60/\text{yr}$$

Assuming a 15-yr useful life of the water-saving kit, the lifetime savings are:

$$\text{Savings Total per pump} = (\text{Total Savings/yr per pump}) * \frac{((1+3.5\%)^{15}) - 1}{(3.5\% * (1+3.5\%)^{15})}$$

$$\text{Savings Total per pump} = (\$706.60) * \frac{((1+3.5\%)^{15}) - 1}{(3.5\% * (1+3.5\%)^{15})} = \$8,138.20$$

This would result in water cost savings of \$706.60/yr or \$8,138.20 saved over the life of the pump.

### C.10.4 Investment

Installation data is based on a 2005 University of Wisconsin field evaluation study with costs normalized to 2014. The water-saving kit price is

from med-parts.com. The allowance for overhead and profit adds 10% to the cost of materials and labor:

$$\begin{aligned}\text{Investment (per kit)} &= \text{Adjusted Labor} + \text{Material} + \text{O\&M costs} \\ \$2,609 + \$2,663 + \$527 &= \$5,799\end{aligned}$$

### **C.10.5 Payback**

The simple payback would be:

$$\$5,799 / \$760.60/\text{yr} = 8.21 \text{ yrs}$$

Assuming a 15-yr useful life of a water-saving kit and assuming one is installed, the SIR would be:

$$\begin{aligned}\text{SIR} &= \text{Savings Total for 1 water-saving kit} / \text{Investment Total for 1 water-saving kit} \\ \text{SIR} &= \text{Lifetime Savings Total for 1 kit} / \text{Investment Total for 1 kit} \\ \text{SIR} &= \$8,138.20 / \$5,799 = 1.4\end{aligned}$$

This project is justified economically.

### **C.10.6 Best practice recommendations**

In addition, the following are suggested best practices to conserve water when using the autoclave in lieu of installing a water-saving kit:

- Install automatic shutoff valves, when possible, to shut off water flow to the unit when not in use. If shutoff is not possible, determine the minimum flow the unit can sustain and set it to this level.
- If possible, shut down the sterilizer when not in use.
- Recycle steam condensate and non-contact cooling water from sterilizers to use as makeup water in cooling towers or boilers.
- As old sterilizers wear out, replace them with water efficient models with automatic shutoff of recirculation water.
- Run the sterilizer or autoclave with full loads only. If the device currently being used is too large to routinely run full loads, it should be replaced with a smaller-capacity model.

## Appendix D: Detailed Discussion – Group 2 ECMs/WCMs

### D.1 ECM HVAC-2: Convert CV pumping systems to variable volume

Table D-1. Projected savings, investments, and paybacks associated with converting CV pumping systems to variable volume.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
611.6		611.6	\$6,528	\$39,000	5.97	2.38

#### D.1.1 Existing conditions

There are currently large numbers of AHUs, FCUs, reheat coils and other terminal units that receive hot water and chilled water from the central utilities plant. The central plant supplies hot and chilled water to the ERDC-CERL Complex 24/7/365. Each of the main buildings has hot and chilled water distribution pumps that operate continuously at constant flow, even during periods when there is little or no heating or cooling load at the AHUs. When there is a reduced heating or cooling load, 3-way valves at each air handling unit divert the supply water through bypass piping directly to the return piping. This wastes considerable pumping energy and, in the case of the chilled water system, adds energy (heat) to the chilled water loop that needs to be removed by the chillers.

#### D.1.2 Solution

Install VFDs on the existing hot and chilled water distribution pumps to supply only as much hot water or chilled water to the buildings as the AHUs and other heating/cooling loads require.

Figure D-1 shows a schematic of the existing heating hot water system serving Bldgs 1 and 2. The hot water system serving Bldg 3 is similar, but not shown in this figure. Note that all pumps in the figure are constant volume. Each pump shown in the figure actually represents a pair of pumps with one pump serving as the “lead” pump and the other serving as a backup. At least one pump in each pair currently operates 24/7/365.

Figure D-1. Existing hot water distribution system for Bldgs 1 and 2.

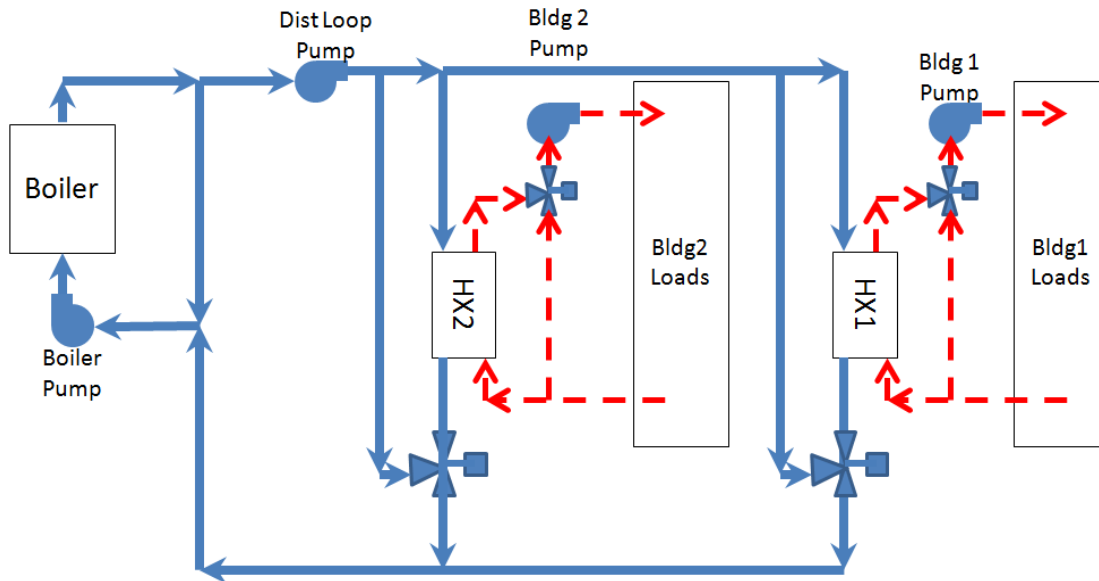
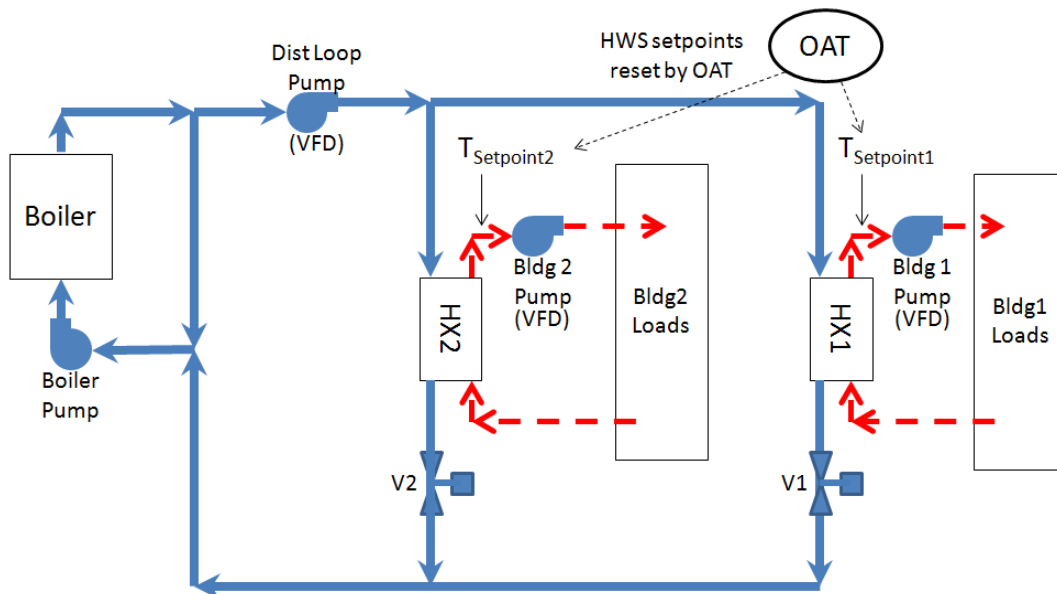


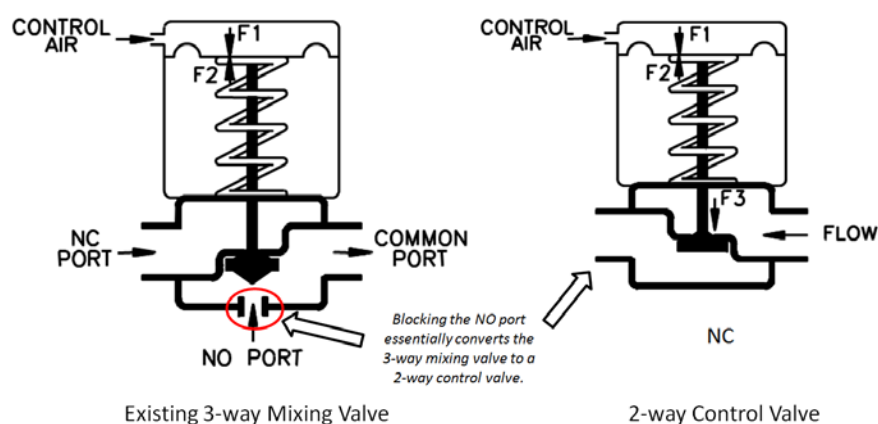
Figure D-2 shows the proposed hot water distribution system configuration for Bldgs 1 and 2. No change is proposed to the Boiler Pump, but the remaining pumps will be equipped with VFDs. This would allow these pumps to ramp up or down as needed to adjust hot water flows to the actual heating loads to take advantage of potential energy savings.

Figure D-2. Proposed hot water distribution system configuration.



To take advantage of the potential energy savings of a variable volume pumping system, many of the existing 3-way mixing valves serving AHUs, FCUs, reheat coils and other hot water terminal devices should be replaced with 2-way control valves. As shown in Figure D-3, it is possible to effectively convert a 3-way mixing valve to a 2-way control valve by merely plugging or valving off the mixing valve's bypass port. Fortunately, most of the existing 3-way mixing valves have a shutoff valve in the bypass piping, making it very easy to implement this change.

Figure D-3. Conversion of a 3-way mixing valve to a 2-way valve by blocking off the bypass port.



Additionally, pressure sensors will need to be installed in the hot water supply piping and existing pneumatic temperature sensors in the mechanical rooms will need to be replaced. Controllers will need to be installed in each mechanical room and VFDs installed on each pump.

### D.1.3 Savings

There are currently a number of hot water pumps supplying hot water to Bldgs 1, 2, and 3 from the Utility Bldg. Some of these pumps operate 24/7/365. Assuming that a 5 HP, 90% efficient pump motor were to operate 24/7/365, the annual energy cost (only) to operate that pump would be:

$$5 \text{ HP} * 0.746 \text{ kW/HP} / 0.9 * 24 \text{ hr/day} * 365 \text{ days/yr} * \$0.0365/\text{kWh} = \$1,325/\text{yr}$$

Other pumps operate only during scheduled occupied hours. Assuming that the same pump were to operate 12 hours per day, 5 days per week, the annual energy cost would be:

$$\$1,325 * 60 \text{ hrs/wk} * 52 \text{ wks/yr} / 8760 \text{ hrs/yr} = \$471.97/\text{yr}$$

Table D-2 lists the existing hot water distribution pumps serving Bldgs 1, 2, and 3.

Table D-2. List of existing hot water distribution pumps.

Pump	HP	Est. Annual "ON" Hrs	Est. Annual kWh	Est. Annual Energy Cost	Remarks
Main Hot Water (HW) Dist Pump 1	5	8,760	36,305	\$1,325.13	Unclear why both Pump 1 and Pump 2 are operating simultaneously or if this is even necessary
Main HW Dist Pump 2	5	8,760	36,305	\$1,325.13	Same as above
Bldg 1 HW (Pump 1)	7.5	4,380	27,229	\$993.86	50% duty cycle, 24/7/365
Bldg 1 HW (Pump 2)	7.5	4,380	27,229	\$993.86	50% duty cycle, 24/7/365
Bldg 2 HW (Pump 1)	10	4,380	36,305	\$1,325.13	50% duty cycle, 24/7/365
Bldg 2 HW (Pump 2)	10	4,380	36,305	\$1,325.13	50% duty cycle, 24/7/365
Bldg 3 HW (Pump 1)	3	8,760	11,150	\$407.00	Assumed to operate 24/7/365, on existing VFD drive
Bldg 3 HW (Pump 2)	3	0	0		Assumed backup to Pump 1
Totals			210,828	\$7,695.24	

In discussing hot water system operations with the UIUC HVAC systems technician, it was unclear why the two main HW distribution pumps delivering hot water from the boilers to Bldgs 1 and 2 were operating simultaneously. He said that he had always seen them both operating and assumed that they were both needed. This analysis assumes that both pumps do not need to be running simultaneously, but a further effort is needed to verify this.

Table D-3 lists the assumed operating cost of a 5 HP pump (90% efficient) operating 24/7/365 with its speed modulated by a VFD based on an assumed annual heating load profile.

Table D-3. Estimated operating cost for a 5 HP pump operating 24/7/365 on a VFD.

% Full Heating Load	Mid-Point of Range	% of Time	Fraction of Full Load Motor Power	VFD kWh	VFD Annual Operating Cost
90 to 100	95%	2%	0.857	622.55	\$22.72
80 to 89	85%	10%	0.614	2229.60	\$81.38
70 to 79	75%	15%	0.422	2297.45	\$83.86
60 to 69	65%	15%	0.275	1495.55	\$54.59
50 to 59	55%	15%	0.166	906.04	\$33.07
40 to 49	45%	10%	0.091	330.83	\$12.08
30 to 39	35%	10%	0.043	155.66	\$5.68
20 to 29	25%	10%	0.016	56.73	\$2.07
10 to 19	15%	10%	0.016	56.73	\$2.07
0 to 9	5%	5%	0.016	28.36	\$1.04
			<b>Totals</b>	<b>8,179.50</b>	<b>\$298.55</b>

If placed on a VFD, the potential annual energy cost savings for a 5 HP, 90% efficient pump that operates 24/7/365 would be:

$$\$1,325.13 - \$298.55 = \$1,026.58.$$

Table D-4 shows the potential annual energy cost savings for all of the pumps listed in Table D-2 if operated by VFDs. These calculations assumed that the pumps would not be operated below 25% of their full speed.

**Table D-4. Potential annual energy and energy cost savings if all HW pumps were converted to variable volume pumping.**

Pump	HP	Est. Annual *ON* Hrs	Est. Current Annual kWh	Est. VFD Annual kWh	Est. Current Annual Energy Cost	Est. VFD Annual Energy Cost
Main HW Dist Pump 1	5	8,760	36,305	8,180	\$1,325.13	\$298.55
Main HW Dist Pump 2	5	8,760	36,305	8,180	\$1,325.13	\$298.55
Bldg 1 HW (Pump 1)	7.5	4,380	27,229	6,135	\$993.86	\$233.91
Bldg 1 HW (Pump 2)	7.5	4,380	27,229	6,135	\$993.86	\$233.91
Bldg 2 HW (Pump 1)	10	4,380	36,305	8,180	\$1,325.13	\$298.55
Bldg 2 HW (Pump 2)	10	4,380	36,305	8,180	\$1,325.13	\$298.55
Bldg 3 HW (Pump 1)	3	8,760	11,150	4,908	\$407.00	\$179.13
Bldg 3 HW (Pump 2)	3	0	0	0	0	0
Totals			210,828	49,898	\$7,695.24	\$1,841.15

The estimated annual energy savings and energy cost savings for converting the hot water distribution systems to variable volume pumping would be 160,930 kWh and \$5,854.09, respectively. Note that these cost savings do not consider any electrical demand cost savings or maintenance costs savings resulting from this proposed change because they would be extremely difficult to predict.

Using a similar analysis, Table D-5 lists the potential annual energy cost savings for converting all of the chilled water pumps in Bldgs 1, 2, and 3 to variable speed pumping. These calculations assumed that the pumps would only be operating 12 hours per day, 5 days per week and 8 months out of the year with one pump operating at a time and the second pump acting as a spare. It was also assumed that the pumps would not be operated below 25% of their full speed.

**Table D-5. Potential annual energy and energy cost savings if all chilled water (CHW) pumps were converted to variable volume pumping.**

Pump	HP	Est. Annual "ON" Hrs	Est. Current Annual kWh	Est. VFD Annual kWh	Est. Current Annual Energy Cost	Est. VFD Annual Energy Cost
Bldg 1 CHW (Pump 1)	5	1,040	4,310	1,235	\$157.32	\$45.08
Bldg 1 CHW (Pump 2)	5	1,040	4,310	1,235	\$157.32	\$45.08
Bldg 2 CHW (Pump 1)	5	1,040	4,310	1,235	\$157.32	\$45.08
Bldg 2 CHW (Pump 2)	5	1,040	4,310	1,235	\$157.32	\$45.08
Bldg 3 CHW (Pump 1)	5	1,040	4,310	1,235	\$157.32	\$45.08
Bldg 3 CHW (Pump 2)	5	1,040	4,310	1,235	\$157.32	\$45.08
Totals			25,860	7,410	\$944	\$270

Annual electrical energy savings for converting the chilled water distribution systems to variable volume pumping would be 18,450 kWh. The estimated annual energy cost savings for this improvement would be \$673.92. Note that these savings also consider no electrical demand cost savings or maintenance cost savings. Retrofitting both the HW and CHW pumping systems would save 179,380 kWh and \$6,528 of electrical energy costs per year.

#### **D.1.4 Investment**

Implementation costs to convert both the HW and CHW pumping systems to variable volume are estimated at \$39,000 (Table D-6).

**Table D-6. Estimated implementation cost for HW and CHW systems.**

Item	Qty	Material Cost (ea)	Installation Cost (ea)	Subtotal Cost
VFD – 10 HP	2	2,000	1,000	\$6,000
VFD – 7.5 HP	2	1,500	1,000	\$5,000
VFD – 5 HP	10	1,000	750	\$17,500
VFD – 3 HP	1	750	750	\$1,500
Temperature Sensor	3	150	200	\$1,050
Pressure Sensor	7	150	200	\$2,450
Controller (LonWorks)	3	500	500	\$3,000
Enclosures, Wiring, etc.				\$1,000
Integrate into ERDC-CERL BAS system				\$1,500
Totals				\$39,000

#### **D.1.5 Payback**

With a total savings of \$6,528 per year, the simple payback is 5.97 years. Assuming a useful life of 20 years, the estimated SIR would be 2.38. This could be a very attractive project. It must be noted, however, that before implementation, this project should be coordinated with UIUC to make sure that it does not conflict with any planned system upgrades.

## D.2 ECM HVAC-3: Install fume hood controls

Table D-7. Projected savings, investments, and paybacks associated with the installation of fume hood controls.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
812	4,337	5,149	\$43,458	\$170K	3.9	3.6

### D.2.1 Existing conditions

ERDC-CERL has a total of 22 laboratory fume hoods, all located in Bldg 1. Most (19) of these units are located in the west side of the building, while the rest (3) are on the east side. All of the hoods appear to be CV, operating in two modes: ON or OFF. All of the hoods have sashes and ON/OFF buttons. The newer models have controls that shut down the fan when the sash is completely closed. One fume hood seems to be nonoperational and appears to be used for storage. Four of the units are biological fume hoods, which were not considered in this analysis. Table D-8 lists the fume hoods and pertinent information.

Table D-8. Fume hoods for retrofit.

No.	Room#	Makeup Air Unit Type	Designator	Description / Comments	POC
1	1011	MZ	FH-03	Mfr: Duralab. Face velocity: 107 lfpm.	
2	1011	MZ	FH-04	Mfr: Duralab. Face velocity: 108 lfpm.	
3	1011	MZ	FH-05	Mfr: Duralab. Face velocity: 125 lfpm.	
4	1014	MZ		Mfr: Curtin Matheson Scientific. Model: PL-183 Par # 60114. Face velocity: 120 lfpm.	S. Drozdz
5	1015	MZ		Mfr/Model: Labonca/9902200. 25 gal capacity. Face velocity: 114 lfpm.	D. Cropek
6	1015	MZ		Mfr/Model: Labonca/9902200. 25 gal capacity. Face velocity: 114 lfpm.	D. Cropek
7	1018	MZ	FH-02	Used for paint spraying. Has two FHs. Solvent exhaust is always on.	
8	1018	MZ		Used for solvent exhaust. Always on.	
9	1018	MZ			
10	1024	VAV Box		Labonca.	
11	1024	VAV Box		Labonca.	
12	1037	AHU			
13	1038	AHU		Face velocity: 123 lfpm.	
14	1051	AHU	FH-08		S. Drozdz
15	1052	AHU	FH-01		
16	1210	PKG	FH-06	Allied Fischer Scientific / Safety Flow. Face velocity: 120 lfpm.	S. Drozdz
17	1218	PKG	FH-07	May be replaced in 2010 or 2011	
18	1219	PKG		Labconco. Model 48830. Face velocity: 129 lfpm.	

### D.2.2 Solution

It is proposed that ERDC-CERL use a technique implemented by the University of Texas at Austin (UTA), which converts a CV fume hood to VAV. Adams and Alderman (2009) describe the technique, which uses an air valve (Figures D-4 and D-5) to allow more or less air to be exhausted based on a sensor that monitors whether the sash is above or below a specified height (two-stage monitoring system) or alternatively provides continuous monitoring of sash position (continuous monitoring system). In either case a controller modulates the flow rate depending on sash position.

Figure D-4. Schematic diagram of air valve controlled by sash position/height.

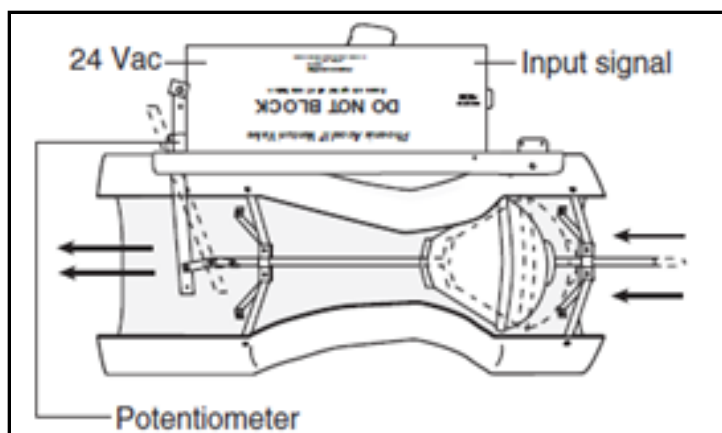
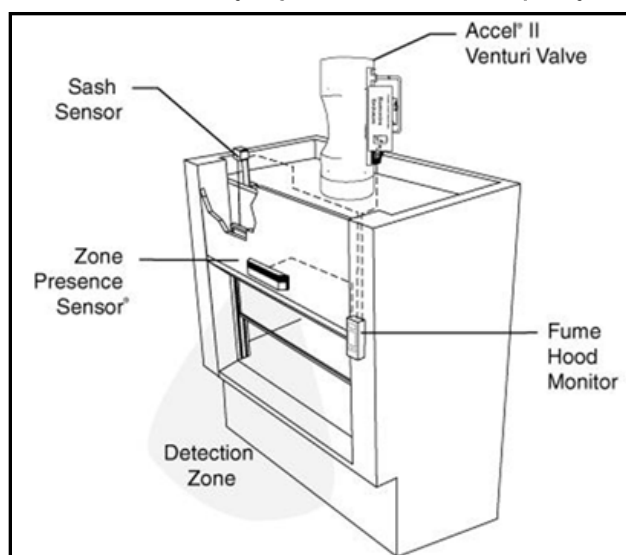


Figure D-5. Air valve used to control air flow in fume hoods.



Figure D-6 shows a generic illustration of an installed control valve including a “detection zone” (not intended for inclusion in this renovation) in which a motion sensor can detect if an operator is present and correspondingly adjusts the flow.

Figure D-6. Face velocity adjusted based on occupancy sensor.



### D.2.3 Savings

The UTA study indicates that a VAV fume hood can save approximately \$3/cfm/yr for a single fume hood. One of ERDC-CERL's newest installed fume hoods has a maximum nominal inflow of 527 cfm – this seems to be typical of all hoods. Retrofitting 18 fume hoods would save \$28,458/year.

### D.2.4 Investment

Replacing an old CV fume hood with a new VAV fume hood can cost \$4,000-6,000. However, Phoenix Controls has valves and sensors that may be retrofit to existing CV fume hoods to convert them to VAV for a fraction of the price. The components and approximate pricing (from the UTA study) are listed below. Some sensors are used for monitoring and not for the VAV retrofit and therefore can be omitted if necessary. As such, the following cost estimate is somewhat conservative:

- VAV system parts: \$1,100 (includes phenol coating for corrosion protection, \$200).
- X30 Series Fume Hood Monitor: \$750.

- Usage Based Controls (UBC): \$600 occupancy sensor for fume hoods that decreases the face velocity (flow rate) when no fume hood operators are present.
- Average installation time for each retrofit: 6 hours.
- Two person crew paid at a rate of \$200 per hour for a total of \$1,200.
- Total retrofit cost per hood: \$3,650.
- Conduct fume hood survey/finalize design: \$4,000.
- Total retrofit costs for 18 hoods: \$69,700.

Retrofitting an existing CV fume hood to a VAV fume hood is less expensive than purchasing a new one.

This retrofit would also require that the makeup air units be fitted with controls that coordinate them with the fume hoods so that the spaces are correctly pressurized. The suggested method is to install LON-based DDC controls. The fume hoods under consideration are served by six units (1 VAV box served by an AHU, three AHUs, and two packaged units). The units also serve other areas that would benefit from converting controls to LON-based DDC. It is estimated that each AHU would cost approximately \$20k for a full retrofit and packaged units would cost approximately \$10k each. A total of \$100k is expected to cover the cost for all units associated with these fume hoods. This brings the total retrofit cost of this ECM to \$170k.

#### **D.2.5 Payback**

The savings of converting the AHUs, and packaged unit controls to DDC are difficult to estimate, but are expected to be at least \$15k/yr. The total savings associated with retrofitting the fume hoods and upgrading the AHU and packaged unit controls to DDC is estimated to be \$43,458/yr. As a result, this ECM would result in a simple payback of 3.9 years. At an expected useful life of 20 years the SIR would be 3.6.

## Appendix E: Detailed Discussion – Group 3 ECMs/WCMs

### E.1 ECM BE-2: Install/upgrade wall insulation, Bldgs 1 and 2

Table E-1. Projected savings, investments, and paybacks associated with installation/upgrade of wall insulation in Bldgs 1 and 2.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
141	366	507	\$23,022	\$221k	9.6	1.8

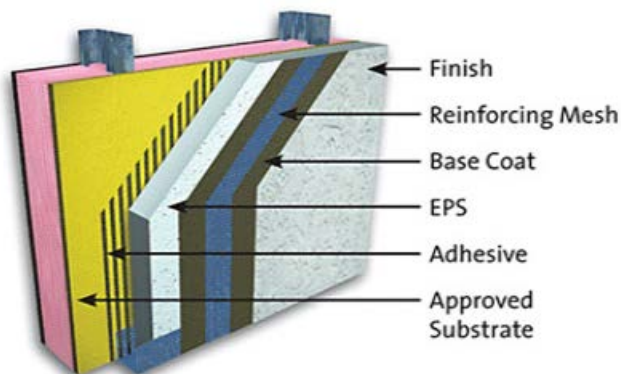
#### E.1.1 Existing conditions

Bldgs 1 and 2 were built with concrete block and brick exterior walls, and have not been subsequently insulated. Poorly insulated walls allow for high thermal losses, forcing heating and cooling systems to work harder and/or leaving the occupants uncomfortable.

#### E.1.2 Solution

FEDS recommends installation of insulation with a total R-value of 12.4 on the interior surface of the walls. However given all of the objects that would have to be removed to do this, installation of EIFS (Figure E-1) might be a better option. EIFS can be made to look like most any surface such as the brick at ERDC-CERL. The cost for EIFS is estimated to be about \$10/ft<sup>2</sup>, or \$221k for Bldgs 1 and 2 resulting in a simple payback of 9.6 years.

Figure E-1. EIFS exterior insulation.



### **E.1.3 Savings**

Adding R-12.4 insulation to Bldgs 1 and 2 would save 141 MMBTU/yr in electrical usage and 366 MMBtu/yr in natural gas consumption according to FEDS calculations. Total monetary savings would be \$23k/yr.

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

### **E.1.4 Investment**

As estimated by FEDS, a total of \$148k would be required to install interior wall insulation to Bldgs 1 and 2, however \$221k is believed to be a more realistic cost for EIFS.

### **E.1.5 Payback**

With the above stated total savings (based on external insulation), the simple payback is 9.6 years.

## Appendix F: Detailed Discussion – Group 4 ECMs/WCMs

### F.1 ECM HVAC-4: Shut down central plant boilers during cooling season

Table F-1. Projected savings, investments, and paybacks associated with shutdown of central plant boilers during cooling season.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
0	3,090	3,090	24,700	26,000	1.1	13.5

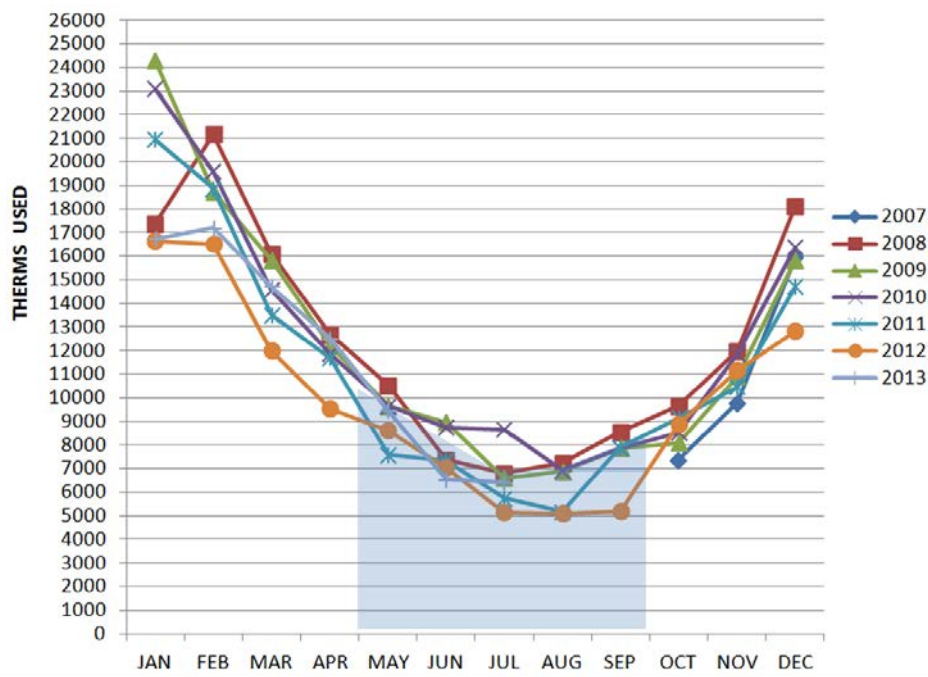
#### F.1.1 Existing conditions

Currently, the central plant boilers in the Utilities Bldg operate year around. This is a questionable practice during the summer cooling season when there should be little or no heating load. There may be a number of locations that, for one reason or another, have a small reheat load. At this writing, these reheat loads were unknown. If these possible reheat loads were identified and measured, there might be more economical ways of meeting these requirements than operating the central plant boilers all year long.

Figure F-1 shows ERDC-CERL's historic natural gas usage by month. One can see that the boilers operate all year long and that there is a sizeable amount of gas consumed during the cooling season months of May through September as shown by the shaded area in the figure. This is a very consistent pattern over the FY07 to FY13 time period.

Note that Bldgs 1 and 2 have their own gas hot water heaters for domestic hot water requirements and Bldg 3 has an electric hot water heater for the same purpose, so the central plant boilers are not needed for supplying domestic hot water.

Figure F-1. Historic ERDC-CERL gas usage by month.



### F.1.2 Solution

It is recommended that a Level II investigation be performed to determine the exact locations and magnitudes of summer heating loads to determine if these loads are valid and/or if they can be handled in a more economical and energy efficient manner. A simple way to perform this investigation would be to merely turn off the central plant boilers for a week during the cooling season and see what impact this has on conditions in Bldgs 1, 2, and 3. Where there might be a possibility of an adverse impact (such as subcooling of office spaces or conference rooms or high humidity conditions in a copier room), coordinate with ERDC-CERL's DPW and UIUC F&S to identify areas of concern and instrument them with temperature/humidity data loggers to measure and record the actual conditions in these areas during the period of the test.

Wherever unacceptable temperature or humidity conditions are identified by this test, the next step would be to determine the magnitude of any heating or dehumidification requirement and investigate alternate means of satisfying the requirement.

### F.1.3 Savings

Assuming that the boilers could be turned off during the cooling months of May through September, a very rough estimate of the potential savings can be made. Table F-2 lists the monthly gas usage based on the 2013 data points shown Figure F-1.

Table F-2. Estimated natural gas usage by central plant boilers during the cooling season.

Month	Usage (Therms)
May	8,600
June	7,000
July	5,100
August	5,100
September	5,100
Total	30,900

During the cooling season, roughly 30,900 therms (3,090 MMBTU) could possibly be saved. At \$8.01612/MMBTU of natural gas, the thermal energy savings alone would be \$24,700 per year. There would also be significant electrical energy and demand savings during this period since the boilers and associated pumping systems would also be turned off.

### F.1.4 Investment

Until a Level II investigation is conducted, it would be very difficult to estimate the investment cost. The implementation cost of this investigation would be about a week of an engineer or technician's time. Assuming that some type of system (at a cost of \$20k) needs to be installed to handle any identified reheat loads, labor costs for the investigation (at \$150 per hour) would be:

$$\$150 \times 40 \text{ hours} = \$6,000.$$

The (very rough) total investment estimate would then be \$26k.

### F.1.5 Payback

The simple payback would be 1.1 years and the SIR would be 13.5, assuming a useful life of 20 years.

A Level II analysis is highly recommended.

## Appendix G: Detailed Discussion – Non-Viable ECMs/WCMs

### G.1 ECM HVAC-5: Upgrade FCUs in Bldg 1 to LonWorks controls

Table G-1. Projected savings, investments, and paybacks associated with upgrade of FCUs in Bldg 1 to LonWorks controls.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
11.5	156	167.5	1,374	42,000	30.6	NA

#### G.1.1 Existing conditions

The existing controls for the 28 FCUs in Bldg 1 are simple thermostats with a temperature setting and five modes (Off, Auto, Low, Medium, and High). Users typically do not turn the units off, even when they are gone for extended periods of time such as vacations or travel duty. Most offices have occupancy sensors, which control lighting.

#### G.1.2 Solution

Install LON-based networked thermostats in conjunction with occupancy sensors. Coordinate occupancy status with the FCU thermostat's temperature setpoint. This was done in Bldg 2 and has been successful in saving energy.

#### G.1.3 Savings

It is assumed that the existing FCUs operate 24/7/365 in response to individual thermostats in the occupied zones. The thermostats do not have a night setback function. The analysis of potential savings assumed that the thermostats could be programmed to operate from 0600 to 1800 hrs, Monday through Friday for a total of 60 hrs/week, which would reduce operational hours by 108 hrs/week.

The heat transfer coefficient of the areas served by the FCUs was calculated to estimate the energy savings by operating the HVAC systems from 0600 to 1800 hrs, Monday through Friday. The areas served have approximately 4,083 ft<sup>2</sup> of roof area at an estimated R-value of 24, an estimated

2,520 ft<sup>2</sup> of outside wall area at R-2 and 980 ft<sup>2</sup> of window area. The windows are single-pane and metal-framed. For this purpose, the windows were assumed to have an R-value of 0.79.

Energy flow through the building envelope is calculated as:

$$q = q_{roof} + q_{walls} + q_{windows} \quad \left[ \frac{BTU}{hr} \right]$$

$$q = \frac{Area_{roof} \times \Delta T}{R_{roof}} + \frac{Area_{walls} \times \Delta T}{R_{walls}} + \frac{Area_{windows} \times \Delta T}{R_{windows}}$$

$$q = \Delta T \times \left( \frac{Area_{roof}}{R_{roof}} + \frac{Area_{walls}}{R_{walls}} + \frac{Area_{windows}}{R_{windows}} \right)$$

$$q = \Delta T \times \left( \frac{4,083}{24} + \frac{2,520}{2} + \frac{980}{0.79} \right) = 2,671 \times \Delta T \quad \left[ \frac{BTU}{hr} \right]$$

It was assumed unoccupied hours were 1800 to 0600 hours Monday through Friday and weekends, which equates to 108 hours per week. The setpoint setback was assumed to be 10 °F. According to weather data, the outside air temperature is above 65 °F during unoccupied hours for 1,515 hours per year and below 65 °F 4,101 hours per year. Assuming these hours correspond to a call for heating and cooling, the savings are:

- for cooling:

Savings = 2,671 x 10 x 1,515 = 40.4 MMBtu/yr. An efficiency of 1 kW/Ton of cooling would equate to 3,372 kWh/yr or \$124/yr.

- for heating:

Savings = 2,671 x 10 x 4,101/0.7 = 156 MMBtu/yr or \$1,250/yr assuming a heating system efficiency of 0.7.

#### **G.1.4 Investment**

The estimated investment for LON-based thermostats for the 28 units is \$42k.

#### **G.1.5 Payback**

The simple payback for implementing this change would be 31 years. This is not a very attractive ECM. However, less expensive thermostats that are not networked might provide the same savings. However, necessary modi-

fications to the controls, valves, and other components are expected to cost nearly as much as the LON-based thermostat option. There is no payback over the expected useful life of this ECM.

## G.2 ECM HVAC-6: Replace central plant chillers

Table G-2. Projected savings, investments, and paybacks associated with central plant chiller replacement.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
995	0	995	11,100	239,000	21.5	NA

### G.2.1 Existing conditions

Bldgs 1, 2, and 3 are served by two 170-ton electric chillers (York Codepack rotary screw, model YSDBCA50CFAS, manufactured 1993) capable of a total cooling capacity of 340 tons based on 10 °F differential using R-22 refrigerant. The Utility Bldg has space for an additional chiller.

Based on the chillers' type and age, their energy use is estimated at 1 kW/ton.\* A thermal storage tank capable of storing 300 tons-hours of cooling capacity was added to the system and one of the chillers was modified to deliver low temperature glycol to the thermal storage tank. The chillers and the thermal storage tank share a common primary loop in the Utility Bldg. Two pumps circulate water through the chillers and around the primary loop.

### G.2.2 Solution

Replace the existing chillers (Figure G-1) with more efficient models. Modern chillers are much more efficient than the currently installed chillers. Several manufacturers now offer magnetic bearing chillers with IPLVs as low as 0.29 kW/ton. One drawback would be the loss of the thermal storage system resulting in a higher demand charge.

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\* Gary Hamilton, Engineered Systems, July 2014, page 32.

Figure G-1. One of two existing central plant chillers.



### G.2.3 Savings

The following data and assumptions were used to estimate the savings:

- CDD = 1,189 (Based on cooling requirement at 65 °F).
- Cooling design temperature = 90 °F.
- Average efficiency of the old and new chillers is 1.0 kW/ton and 0.29 kW/ton, respectively.
- EFLH = 1,141 hours per year.
- The chillers are properly sized.

Savings are calculated as:

$$\text{Savings} = \text{Capacity} \times (E_{\text{old}} - E_{\text{new}}) \times \text{EFLH}$$

where:

Capacity is in tons

E is in kW/Ton

EFLH = Equivalent Full Load Hours (based on weather data, the equivalent hours the chillers would run at full load per year)

The estimated savings come to 291,752 kWh worth about \$11.1k.

### G.2.4 Investment

A centrifugal chiller of the same capacity would be expected to cost approximately \$199k. The premium for a magnetic bearing model would be about 20%, so the expected cost would be \$239k.

### G.2.5 Payback

This project would have a relatively poor payback of 21 years. Based on the financials, this should not be a high priority. However, as these chillers age, become less efficient, and require more maintenance; and most importantly, as R-22 refrigerant becomes more costly and difficult to obtain, this project will make more sense.

## G.3 ECM LI-8: Upgrade existing 2x4-ft fluorescent light fixtures

Table G-3. Projected savings, investments, and paybacks associated with fluorescent light fixture upgrade.

Energy Savings (MMBtu)			Savings (\$/yr)	Investment (\$)	Simple Payback (yrs)	SIR
Elec	Thermal	Total				
45	0	45	\$706	\$8,497	12.04	1.18

Note: Numbers posted above reflect upgrade of 100 fixtures

### G.3.1 Existing condition

Many private offices, cubicle spaces, conference rooms, and corridors are lighted by 2-lamp T-8 fluorescent fixtures, which were not upgraded in a lighting retrofit project a couple of years ago. Many of these existing fixtures were installed in a lighting upgrade project back in the early 1990s. In many cases, these fixtures are fitted with paracube or parabolic lenses, which tend to be inefficient (much of the light remains trapped inside of the fixture), and which distribute the light very poorly. There is potential for energy savings and, in many cases, improved lighting by upgrading these fixtures.

### G.3.2 Solution

In 2012, ERDC-CERL executed a project to upgrade lighting systems in offices, conference rooms, and other common areas. The project involved retrofitting existing 2x4-ft 2-lamp recess-mounted light fixtures with a new reflectors and delamping from two lamps to a single T8 32-watt lamp. High Kelvin 6500K lamps were selected to take advantage of scotopic lighting effects. In most cases, this lighting system was found to provide adequate light levels at significantly reduced wattage.

Although many fixtures were retrofitted during the 2012 project, many unretrofitted fixtures remained. This ECM would retrofit the remaining

2x4-ft 2-lamp fixtures by delamping to 1-lamp T-8 fixtures. This would include replacing the reflectors inside of the existing fixtures, installing a 6500K lamp, and replacing the existing paracube and parabolic lenses with clear prismatic lenses.

### G.3.3 Savings

This analysis will be based on retrofitting one existing 2x4-ft 2-lamp T8 fixture in the following locations, as described above. Assumed lamp power consumption would be  $2 \times 32 \text{ watts} = 64 \text{ watts}$ . Allowing approximately 5% of additional energy consumed by the ballast, the existing fixture would consume approximately 67.2 watts.

It is assumed that the retrofitted fixture would consume 32 watts less.

Table G-4 lists savings of retrofitting existing 2x4-ft 2-lamp fixtures assuming fixtures in the indicated locations.

Table G-4. Energy and cost savings of retrofitting existing 2x4-ft 2-lamp fixtures.

Location	Daily ON hours	Weeks per year	Annual ON hrs	Annual energy savings (kWh)	Demand savings (kW)	Annual energy and demand cost savings (\$)
Private office	9	48	2,160	69.1	0.032	\$4.72
Cubicle space	12	52	3,120	99.8	0.032	\$5.84
Conference room	6	52	1,560	49.9	0.032	\$4.02
Corridor	16	52	4,160	133.1	0.032	\$7.06

### G.3.4 Investment

Required investments include:

- 1-lamp retrofit reflector kit (Figure G-2) for 2x4-ft troffer at \$10.40 each
- 1-lamp high power ballast at \$9.98 each
- F32T8 865 XPS lamp (6500K) at \$3.09 each
- Replacement door frame with prismatic lens at \$24 each.

The total materials cost would be \$47.47 per fixture.

The estimated labor would be  $\frac{1}{2}$  hour of electrician's labor at \$75 per hour or \$37.50 per fixture.

The total investment per fixture would be \$84.97.



#### **G.4.1 Existing conditions**

CERL currently has no renewable energy generation capabilities. Until recently there was a large open area north of the Main Complex on which renewables could have been installed. However, recently constructed research projects have since taken up much of that available space.

#### **G.4.2 Solution**

Install a small scale wind turbine, photovoltaics, and/or solar hot water generator.

### **G.5 Savings, Investment and Payback**

A small scale wind turbine system comprised of four Gala Wind 133 turbines capable of producing 11 kW each was analyzed. A PV system capable of producing 70 kW was also evaluated as well as an 11,000 BTU/hr solar hot water system. A software tool, the System Advisory Model (SAM) (NREL 2010), was used to analyze these systems at the ERDC-CERL location. No specific location or building was identified for implementation. Satellite-based weather data were accessed, using the coordinates of ERDC-CERL (40.15 Latitude and -88.25 Longitude). As with other ECMs, an electrical cost of \$0.0365/kWh and \$8.01612/MMBTU for natural gas were used.

Table G-5 lists the projected savings, investments and paybacks for these renewable projects. Unfortunately, ERDC-CERL has very limited resources for renewable energy projects. Limited renewable energy resources combined with relatively low electricity and natural gas rates cause these projects to be economically non-viable.

Economically ERDC-CERL could best satisfy the Army's renewable energy requirements by purchasing Renewable Energy Credits (RECs). Ameren Illinois sells blocks of RECs at \$10/1,000 kWh. EPACT 2005 requires Federal agencies to obtain 7.5% of their electrical consumption from renewable sources. At the 2013 consumption level, this would require 243,751 kWh/yr of RECs at a cost of \$2,430.

## **Appendix H: Observations and Recommendations – Lighting Systems**

### **H.1 Improve lighting when performing spot replacement**

Spot replacements of lamps, ballasts, and fixtures on end-of-life or in-service failure present opportunities to upgrade the lighting technology and delamp overlit areas. When replacing lamps, ballasts, and fixtures, the most energy efficient and cost effective technologies currently available should be selected. Lighting technologies are constantly improving and costs for these advanced technologies (such as LED lighting systems) are constantly declining. Before replacing failed systems with like technologies, one should investigate the state of lighting technologies to the most cost effective, energy efficient technologies available.

### **H.2 Influence human behavior**

In “owned” spaces that have switches, such as individual offices and laboratory spaces, education and motivation can often be more cost effective than the materials and labor needed to install occupancy sensors. Education and motivation can include stickers on switches and quarterly group emails. The ERDC-CERL Green Campus Initiative might be helpful in promoting energy efficiency awareness.

In “non-owned” spaces, including copy rooms, break rooms, conference rooms and restrooms, occupancy sensors are usually more cost effective, because in non-owned spaces, if lights are on when somebody comes in, they typically leave the lights on when they exit.

### **H.3 Use low-BF ballasts when delamping is not possible**

Ballast factor (BF) is a measure of the actual lumen output for a specific lamp-ballast combination relative to the rated lumen output measured with a reference ballast under ANSI test conditions (open air at 25 °C [77 °F]).

BF is not a measure of energy efficiency. Although a lower BF reduces lamp lumen output, it also consumes proportionally less input power. As

such, careful selection of a lamp-ballast system with a specific BF allows designers to better minimize energy use by “tuning” the lighting levels in the space. For example, in new construction, high BFs are generally best, since fewer luminaires will be required to meet the light level requirements. In retrofit applications or in areas with less critical visual tasks, such as aisles and hallways, lower BF ballasts may be more appropriate (Eley et al. 2003).

When delamping is not possible, such as in fixtures that only have one lamp, low-BF ballasts should be used. For example, a 4-ft fixture with 1-F32T8 735 and 1-lamp generic 0.88 BF instant start ballast consumes 31W. This fixture could be retrofitted with one F32T8 850 lamp and a 1-lamp, extra efficient, 0.71 BF program start ballast, which consumes 24W (a 23% reduction) while providing at least as much light.

#### **H.4 Eliminate parabolic louvered troffers**

ERDC-CERL has many parabolic louvered troffers (recessed fixtures), measuring 2x4-ft and 2x2-ft. Parabolic louvers are often used in these fixtures. Although parabolic louvers were quite popular in the late 1980s through mid-1990s, mainly because the curved Cathode Ray Tube (CRT) computer screens of the time were so glare sensitive, it is now widely accepted that they should not be used because:

- LED and LCD flat screen monitors have replaced CRT monitors and provide their own adequate, glare-free light for computer work.
- Parabolic louvered troffers provide only 65 - 75% fixture efficiency, i.e., 25 – 35% of the light from the lamps never gets out of the fixture.
- Parabolic louvered troffers produce overhead glare, which can cause eye strain and headaches.
- Parabolic louvered troffers produce insufficient vertical footcandles.
- Parabolic louvered troffers produce excessive contrast ratios, which can cause eye strain and headaches.
- Parabolic louvered troffers produce a “cave effect” caused by dark ceilings and upper walls.

Parabolic louvered troffers have never been recommended for hallways and other areas, but ERDC-CERL has many parabolics in halls and other non-computer areas. Delamping these fixtures while keeping the parabolic

louvers can be problematic because it ruins proper cut-off angles and creates excessive glare.

It is recommended that ERDC-CERL not accept new buildings or retrofit projects with parabolic louvers (Figure H-1), and that ERDC-CERL eliminate existing parabolic louvered troffers when the fixtures are scheduled for replacement.

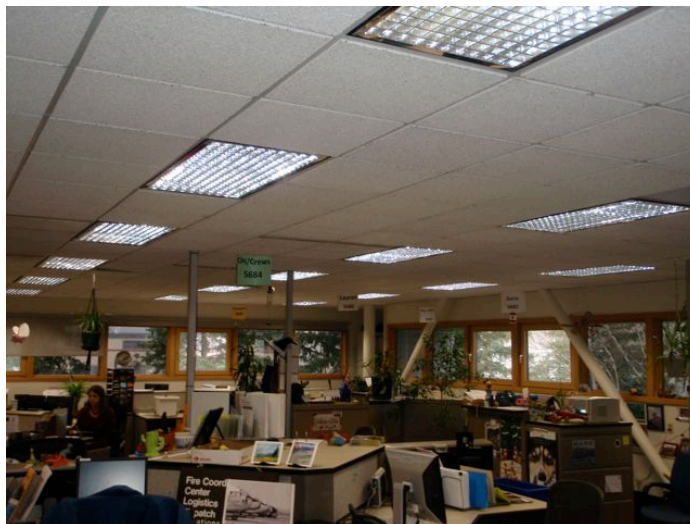
Figure H-1. Parabolic louvered troffer.



## H.5 Eliminate paracube louvers

Paracube louvers (Figure H-2) are similar to parabolic louvered troffers, but paracubes have about 1-in. open square cells, which are about 1-in. tall. In some ways, paracubes are even less efficient and functional than louvered parabolic troffers. The top of a paracube louver is constructed with a high percentage of plastic surface area compared to the open area that light passes through. Paracube louvers should be replaced with large scale, clear prismatic lenses, in conjunction with delamping. Large scale, clear prismatic lenses are much more functional and aesthetically appealing than the typical clear small scale prismatic lenses.

Figure H-2. Paracube louvered troffers.



## **H.6 Eliminate white lenses**

White lenses typically block about 30% of light produced, compared to only about 10% for clear prismatic or ribbed lenses. Therefore, white lenses should be replaced when the fixture is delamped or when the fixture is converted to a lower BF.

## **H.7 Minimize lamp and ballast types**

When possible, replacement of seldom-used lamp and ballast types with the predominant, high performance F32T8 or F17T8 lamps with extra efficient ballasts will reduce maintenance and inventory costs.

## Appendix I: Irrigation Guidance

Table I-1 summarizes irrigation guidance.

Table I-1. Irrigation guidance.

Policy	Applies To		Criteria/Requirement	Source
	new & major renovation	existing		
EO 13423 (2007)	X	X	Encouraged procurement of WaterSense® products and services	
DOE Supplemental Guidance			Guidance for meeting water conservation goals of EO 13423	<a href="http://www1.eere.energy.gov/femp/program/waterefficiency_goalguidance.html">http://www1.eere.energy.gov/femp/program/waterefficiency_goalguidance.html</a>
EISA 2007	X		Restore pre-development hydrology	
EO 13514 (2009)	X	X	Reduce landscape water use by 2%/yr	
Army SDD (27Oct2010)	X		references ASHRAE 189.1-2009; outdoor use 50% reduction	
AR 420-1 (2/2008)	X	X	use reclaimed or recycled water for landscape irrigation	Energy conservation and mgmt guidelines, Chapter 22-12 e. Water, pg. 295
DRAFT LID Guidance-22Mar13			use appropriate landscaping	<a href="https://mrsi.usace.army.mil/sustain/SitePages/CX/Hydrology%20LID.aspx">https://mrsi.usace.army.mil/sustain/SitePages/CX/Hydrology%20LID.aspx</a>
UFCs			Unified Facilities Criteria; apply to all of DoD	<a href="http://www.wbdg.org/ccb/browse_cat.php?o=29&amp;c=4">http://www.wbdg.org/ccb/browse_cat.php?o=29&amp;c=4</a>
3-210-10: LID	X		Criteria for EISA-required Low Impact Development	<a href="http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf">http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf</a>
1-200-02: HPSB	X		High Performance and Sustainable Building Requirements	<a href="http://www.wbdg.org/ccb/DOD/UFC/ufc_1_200_02.pdf">http://www.wbdg.org/ccb/DOD/UFC/ufc_1_200_02.pdf</a>
ECBs			Engineering Construction Bulletins; apply to USACE projects	
HPSB (2/2013)	X		wtr eff landscape-reduce landscape potable water by 50%	<a href="http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb_2013_5.pdf">http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb_2013_5.pdf</a>
Standards				
ASHRAE 189.1-2009	X		60% of improved landscape shall be bio-diverse; (excludes athletic fields, golf courses, driving ranges); hydrozoning of irrigation systems by plant material; sprinklers shall not spray water on Bldg or within 3 ft; must use qualifying smart irrigation controller (SWAT) (temporary irrigation systems are exempt); subsystem metering on landscape controller for areas >25 KSF; prescriptive option includes requirement for municipally reclaimed and/or alternate onsite water for golf courses	
LEED NC	X		Water Efficiency Landscape Credit (WE1) is reqd	
Water Sense®	X	X	Landscape Irrigation Controllers	<a href="http://www.epa.gov/WaterSense/products/controltech.html">http://www.epa.gov/WaterSense/products/controltech.html</a>
Other Resources				

Policy	Applies To		Criteria/Requirement	Source
	new & major renovation	existing		
WBDG			Many references for high performance buildings	<a href="http://www.wbdg.org/">http://www.wbdg.org/</a>
RPF Wizard for MILCOM			Para. 4 & 5; Specs can be copied for use in other projects	<a href="http://mrsi.usace.army.mil/rfp/Shared%20Documents/Forms/AllItems.aspx">http://mrsi.usace.army.mil/rfp/Shared%20Documents/Forms/AllItems.aspx</a>
Public Works Tech Bulletins			"How to" pubs that address practical problems	<a href="http://www.wbdg.org/ccb/browse_cat.php?c=266">http://www.wbdg.org/ccb/browse_cat.php?c=266</a>
FEMP BMPs			#4: Water Efficient Landscaping; #5: Water Efficient Irrigation	<a href="http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html">http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html</a>
Irrigation Association			Smart Water Application Technologies (SWAT): products, protocols, case studies, stakeholders	<a href="http://www.irrigation.org/swat/">http://www.irrigation.org/swat/</a>
Rainbird			Irrigation Scheduling using ET	<a href="http://www.rainbird.com/landscape/resources/articles/Irrigation-Scheduling.htm">http://www.rainbird.com/landscape/resources/articles/Irrigation-Scheduling.htm</a>
University of Minnesota			Irrigation Scheduling using Checkbook Method	<a href="http://www.extension.umn.edu/distribution/cropsystems/DC1322.html">http://www.extension.umn.edu/distribution/cropsystems/DC1322.html</a>
EO: Executive Order				
EISA: Energy Independence and Security Act				
BMPs: Best Management Practices				
WBDG: Whole Building Design Guide				
UFC: Unified Facilities Criteria				
SDD: Sustainable Design and Development				
LID: Low Impact Development				
ECB HPB: Engineering Construction Bulletin, High Performance Buildings				
LEED NC: Leadership in Energy and Environmental Design, New Construction				

## **Appendix J: Completed and Planned ECMs**

### **J.1 Introduction**

ERDC-CERL and UIUC (the owner of the ERDC-CERL facilities) have been actively pursuing ECMs. This appendix documents these major initiatives. The following measures described here were considered as part of this energy survey, but were found to have already been accomplished, to be currently in progress, or to have been programmed and budgeted for future execution. For these reasons, the analyses provided here are not as thorough as for other ECMs.

### **J.2 Completed initiatives**

#### **J.2.1 Install programmable thermostats on split A/C systems, heat pumps, and packaged A/C units**

Bldgs 1 and 2 and several standalone buildings previously had various split A/C systems, heat pumps, and packaged units that used basic non-programmable, non-networked thermostats. This prevented them from being set back or remotely monitored. This study regards this energy savings opportunity as already implemented. Table J-1 summarizes what was done.

#### **J.2.2 Install networked controls on FCUs - Bldg 2**

Sixty-seven FCUs in Bldg 2 were upgraded to LON-based controls. This allows temperature setback during unoccupied hours, which saves fan, heating, and cooling energy.

Table J-1. Completed programmable thermostat installation at ERDC-CERL.

Bldg No.	Unit Designator	Description	Rooms/ Spaces Served	Tstat Location (existing)	Twist timer location	Provide Occ sensor	Occ sensor typ	Need Zone-Temp Sens	Renovation Category	Renovation comments
1	SS-1-001	Old travel office	1132	On the wall between the two rooms	adjacent thermostat	Y	PIR	-	LON thermostat	
1	PKG-1-001	MO (Kim Swan)	1152, 1153, 1154, 1155, 1156	On wall between Rms 1153 and 1154	adjacent thermostat	N	-	-	LON thermostat	May require Trane Lonworks module.
1	SS-1-002	Kinball & 2 others	1162, 1165, 1166	in rm 1165 on wall opposite the door	Hallway outside 1162.	N	-	-	LON thermostat	
1	SS-1-003	Contracts Office	1167-S	Opposite rm 1169 mounted on support pillar	adjacent thermostat	N	-	-	LON thermostat	
1	SS-1-004	DPW & portion of Contracts Office	1167-N, 1163, 1164, 1168	in Rm 1163 (Les' office) on left (north) wall	adjacent thermostat	N	-	-	LON thermostat	
1	SS-1-005	Composite lab	1205	middle of north wall	adjacent thermostat	Y	2 PIR	-	LON thermostat	
1	PKG-1-002	Lab and offices	1206, 1207, 1208, 1210, 1211, 1212	Rm 1210	adjacent thermostat	N	-	-	LON thermostat	
1	PKG-1-003	Mailroom	1213, 1214	west wall	adjacent thermostat	Y	2 PIR	-	LON thermostat	May require Trane Lonworks module.
1	AHU-1-008	Secure room	1217	middle of west wall	adjacent thermostat	Y	hybrid PIR Ultra-sonic	-	LON thermostat	
2	PKG-2-001	ACE-IT Office	2015, 2016, 2017, 2019	2017	adjacent thermostat	N	-	-	LON thermostat	
2	SS-2-001	Row of offices West of 2120	2121, 2122, 2123, 2124, 2125	2125	Outside Rm 2125 (existing stat is inside 2125)	N	-	-	LON thermostat	
2	SS-2-002	2 Offices along north wall	2132, 2133	2132	adjacent thermostat	Y	2 PIR	-	LON thermostat	
2	SS-2-003	Old TV studio	2136	2136	adjacent thermostat	Y	PIR	-	LON thermostat	
2	SS-2-004	perimeter office in NE corner	2165	2165	adjacent thermostat	Y	PIR	-	LON thermostat	
6	HP-6-001	Solar House	several	middle common area	adjacent thermostat	N	-	-	LON thermostat	Solar house is not currently on TP/FT-10 network.

## **J.3 Planned initiatives**

### **J.3.1 Replace windows in Bldgs 1 and 2**

Bldgs 1 and 2 currently have aluminum framed single-pane windows. These windows have a very poor insulating value (approximately 1.26 BTU/ft<sup>2</sup>-°F) and therefore waste a lot of energy. It is recommended that these windows be replaced with a thermal break aluminum frame double-pane Argon/Low-e window as suggested by FEDS. It is estimated that this would result in a savings of 25,791 kWh/yr electrical energy, 17 kW in peak electrical demand, 254 MMBTU/yr in natural gas, for a total cost savings of \$15,357/yr. This would require an investment of \$188k resulting in a simple payback of 12.2 years and an SIR of 1.4, assuming a 25-year life.

### **J.3.2 Replace/upgrade boilers**

UIUC Facilities and Services Department (F&S) performed a study on the central utility plant\* and concluded that the boiler configuration is not optimal and should be retrofitted. F&S recommended removing one of the 1968 Cleaver Brooks fire-tube boilers and replacing it with two condensing boilers (previously purchased but never installed) and maintaining all remaining heating equipment at the utility plant.

District heating will allow for better capacity distribution, optimized boiler fire rates, and the flexibility of moving to possibly more efficient methods in the future, such as combined heat and power machines or geothermal technology. The existing boilers exceeded their expected life of 25 years and are now approaching 50 years, having been installed in 1969. They are estimated to be 50% efficient, but could be even less efficient. They should be replaced before the next winter season. The inefficient heating system should be completely upgraded.

Although two new condensing boilers are to be installed, there is a need for a third unit to completely replace the 1968 system and provide for future needs. Thought should be given removing the existing heat exchangers and secondary pumps in the Bldg 1 and 2 mechanical rooms and replacing them with modulating valves that respond to local fluid pressure setpoints, thereby cascading back to the utility plant for reduced primary

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\* CERL HVAC Systems Study, March 2014

pump operation and reduced standby heat loss. This could be accomplished in these phases:

1. Replace the most used existing boiler with two pre-purchased, 1000 MBH condensing boilers. Provide optimized sequencing for best energy use by the remaining existing boiler and the two new boilers. When possible, enable outside air temperature reset to reduce the leaving water temperature and improve condensation at boilers. Provide additional DDC to monitor/control temperatures, pumps, and boiler operations automatically through programming.
2. Replace the primary pump(s) with appropriately sized pump(s) to handle the entire system volume and pressure. Add VFDs and fluid pressure sensing devices at this time for future control.
3. Remove the primary heating pump for Bldg 3 in the Utility Bldg., bypassing it directly to the system.
4. Replace the majority of the three-way valves in Bldg 3 with two-way control valves. Add discharge temperature sensors at all terminal units with reheat coils. Provide reheat coils at all VAV boxes for improved comfort and control.
5. Remove the heat exchanger, secondary pumps, and associated equipment in Bldg 2.
6. Replace the majority of the three-way valves in Bldg 2 with two-way control valves. Add discharge temperature sensors at all terminal units with reheat coils.
7. Remove the heat exchanger, secondary pumps and associated equipment in Bldg 1.
8. Replace the majority of the three-way valves in Bldg 1 with two-way control valves. Add discharge temperature sensors at all terminal units with reheat coils.
9. On equipment failure at the TESS facility, consider reconnecting this system to the main Utility Bldg through pipe repair rather than replacing the standalone boiler in the TESS facility.

FEDS estimates the average amount of gas used for generating hot water for heating Bldgs 1, 2, and 3 to be 90,207 therms/year (9,021 MMBTU/year). UIUC estimates the average operational efficiency of the boilers to be 50%. Assuming no modifications to the distribution system and no changes in loads, replacing the existing boilers with units that operate at 70% efficiency on average would save:

$$\text{Savings} = \text{Load} * (1/E_o - 1/E_n) = 45,104 \text{ therms} * (1/.50 - 1/.70) = 25,774 \text{ therms}$$

$$\text{Cost Savings} = \$207\text{k/year}$$

Table J-2 summarizes completed or planned energy conservation projects at ERDC-CERL.

Table J-2. Summary of completed or planned ERDC-CERL energy conservation projects, as of April 2014.

Item	Description	Energy Reduction*	
		Low	High
Completed (within past year)			
DDC Upgrade	HVAC scheduling/setback of Package Units (multiple throughout CERL)	5.1%	7.7%
DDC Upgrade	HVAC scheduling/setback of Fan Coil Units (62 in Building 2)	2.5%	4.4%
Lighting Phase 1	Bldg1 & 2 (spectrally enhanced lighting)	0.7%	0.7%
Lighting Phase 2	Bldg3 & Bldg 1 & 2 misc spaces (spectrally enhanced lighting)	0.6%	0.6%
Lighting Phase 3	Bldg2 highbay (replace metal halides with T8 fluorescent)	0.7%	0.7%
Lighting Phase 4	TESS/shaketable highbay (replace metal halides with T8 fluorescent)	0.2%	0.2%
Roof Insulation	Insulate most of roof (Bldgs 1 and 2)	1.6%	1.6%
Subtotal:		11.4%	15.9%
On-Going			
DDC Upgrade	HVAC scheduling/setback of plant-served AHUs (multiple throughout CERL)	2.7%	9.2%
HVAC Unit Replacements	Executive office (replace old HVAC with Variable Air Volume)	1%	3%
HVAC Unit Replacements	Replace package units: Contracts Office, Rm 2120. Install VFDs on Multizone units in building 2	1%	3%
HVAC Unit Replacements	Replace package units: ECR, Rm 1218 Lab adjacent secure room, Rm 1220 VTC room	1%	3%
Energy Awareness	Ongoing Energy awareness. Kiosk, display boards, other.	1%	10%
Window Replacement	Replace windows	6.3%	6.3%
Subtotal:		13.0%	34.5%
Total:		24.4%	50.4%
Unfunded / Other:	NOT INCLUDED IN CERL ENERGY USAGE BAR CHART		
Fume Hood conversion	Convert to variable flow (appx 17 units)	2.7%	5.4%
Boiler upgrade	Install high efficiency boilers	12.0%	23.0%
Lighting Phase 5	Bldg 2 lowbay 'lighting controls' (Rm 2120)	0.08%	0.15%
In-fill building	New facility/building between buildings 1 and 2	?	?
* 'Energy Reduction' is an estimate as a percentage of CERL's overall energy (gas and electric). Energy savings for some items are very rough estimates (such as HVAC unit replacements).			

## **Appendix K: Compliance Tracking System (CTS)**

Energy conservation projects can be implemented in a number of combinations. They could be grouped by ECM type covering several buildings, or by building. How ERDC-CERL decides to do this may also affect how they choose to enter this information into CTS. The data in Table K-1 were compiled to provide a cross reference that correlates ECMs and specific buildings that can help facilitate entering this information.



## Appendix L: Federal HPSB Checklist

On 24 January 2006, DOE, along with 20 other agencies, signed the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU) to commit to implementing common strategies for planning, acquiring, siting, designing, building, operating, and maintaining High Performance Sustainable Buildings (HPSBs). The MOU establishes a set of Guiding Principles to:

1. employ integrated design principles
2. optimize energy performance
3. protect and conserve water
4. enhance indoor environmental quality
5. reduce environmental impacts of materials.

Adherence to the Guiding Principles will help DOE achieve the following MOU goals:

- reduce the total ownership cost of facilities and the life cycle cost of facilities' environmental and energy attributes
- improve energy efficiency and water conservation and use renewable energy
- provide safe, healthy, and productive building environments
- promote environmental stewardship through responsible land use and material procurement.

Figure L-1 shows the HPSB checklists that were completed for the ERDC-CERL site.

Figure L-1. Tri-Service HPSB score sheet (draft 09 July 2013 questions).

Tri-Service HPSB Score sheet (Draft 09 July 2013 Questions)				
UFC 1-200-02 High Performance Sustainable Building Requirements Compliance Verification				
Sustainable Existing Buildings				
UFC 1-200-02 HPSB Compliance Questions	Yes	IP[1]	N/A [2]	No
<b>4-2 EMPLOY INTEGRATED ASSESSMENT, OPERATION, AND MANAGEMENT PRINCIPLES.</b>				
<b>4-2.1 Integrated Assessment, Operation, and Management.</b>				
1. Have sustainable operations and maintenance practices been incorporated within Installation EMS?	Yes	IP	N/A	No
2. Have existing conditions and operational procedures and/or major systems been assessed for buildings in excess of 5,000 SF to identify areas for improvement?	Yes	IP		No
3. Have building lifecycle energy, water, material use and recycling, and indoor environmental quality operational performance goals been established?	Yes	IP		No
4. Have building management plans been developed and occupant training conducted?	Yes	IP		No
5. Have building operations and maintenance procedures been adjusted based on occupant/user feedback on work space satisfaction?	Yes	IP		No
<b>4-2.2 Re-Commissioning and Retro-Commissioning.</b>				
6. Has the building been commissioned, recommissioned or retro commissioned within the last five years?	Yes	IP	N/A	No
<b>4-3 PROMOTE SUSTAINABLE LOCATION AND SITE DEVELOPMENT.</b>				
<b>4-3.1 Reduce Transportation-Related Greenhouse Gas Emissions.</b>				
7. Is information distributed to building occupants about transportation alternatives, near by amenities, and alternative workplace arrangements?	Yes	IP		No
<b>4-3.2 Integrate with Local Planning.</b>				
8. For large facilities, with more than 100 employees, are regional and local planning and transportation officials consulted with on an annual or biennial basis, as appropriate, to discuss opportunities to coordinate planning efforts and to engage with regional and local integrated plans for transportation and energy choices?	Yes	IP	N/A	No
<b>4-4 OPTIMIZE ENERGY PERFORMANCE.</b>				
<b>4-4.1 Energy Efficiency</b>				
9. Have one of the three options below been used to measure/improve efficient energy performance?			N/A	
Option 1: Demonstrated achievement of an ENERGY STAR® performance score of 75 or higher.	Yes	IP		No

Figure L-1. (Cont'd).

	<b>Option 2:</b> Demonstrated energy use reduction of 20% compared to 2003 .	Yes	IP	?	No
	<b>Option 3:</b> Calculated energy use reduction of 20% compared to ASHRAE 90.1 baseline.	Yes	IP	?	No
10.	Do you require products that are ENERGY STAR®-qualified or meet FEMP-designated efficiency when available?	Yes	IP	?	No
11.	Are products with the lowest standby power consumption required?	Yes	IP	?	No
<b>4-4.2 On-Site Renewable Energy.</b>					
12.	Have renewable energy generation projects been implemented on agency property for agency use, when lifecycle cost effective?	Yes	IP		No
<b>4-4.3 Measurement and Verification.</b>					
13.	Does the building have building level electrical, natural gas, and/or steam meters as applicable, connected to an installation wide energy and utility monitoring and control system?	Yes	IP	N/A	No
<b>4-4.4 Benchmarking.</b>					
14.	Are current building performance data being compared with previous years' performance data in a measurement and tracking tool and used in informing capital investment decisions?	Yes	IP	N/A	No
<b>4-5 PROTECT AND CONSERVE WATER.</b>					
<b>4-5.1 Indoor Water.</b>					
15.	Have one of the two options below been used to reduce indoor potable water use?			N/A	
	• <b>Option 1:</b> Calculations to determine water use equal to or lower than a 2006 UPC or IPC baseline.	Yes	IP		No
	• <b>Option 2:</b> Comparison of water metered data with 2003 building water use data.	Yes	IP		No
<b>4-5.2 Outdoor Water.</b>					
16.	Have one of the three options below been used to reduce outdoor potable water for landscaping?			N/A	
	• <b>Option 1:</b> Demonstrated irrigation water use reduced by 50% compared to conventional practices.	Yes	IP		No
	• <b>Option 2:</b> Demonstrated 50% water use reduction by comparison with 2003 water use data.	Yes	IP		No
	• <b>Option 3:</b> No potable water is used for irrigation.	Yes	IP	?	No

Figure L-1. (Cont'd).

<b>4-5.3 Water Used for Heating and Cooling.</b>				
17.	Have lifecycle cost effective water conservation measures been deployed to improve the building's energy efficiency?	Yes	IP	<input checked="" type="radio"/> No
<b>4-5.4 Measurement of Water Use.</b>				
18.	Does the building have a water meter installed?	Yes	IP	<input checked="" type="radio"/> No
<b>4-6 ENHANCE INDOOR ENVIRONMENTAL QUALITY.</b>				
<b>4-6.1 Ventilation and Thermal Comfort.</b>				
19.	Was the building designed to or does it meet at a minimum ASHRAE Standard 55-2004?			<input type="radio"/> ?
20.	Was the building designed to or does it meet at a minimum ANSI/ASHRAE Standard 62.1-2007?			<input type="radio"/> ?
<b>4-6.2 Moisture Control.</b>				
21.	Have appropriate moisture control strategies been implemented to prevent building damage, minimize mold contamination, and reduce health risks related to moisture?	<input checked="" type="radio"/> Yes	IP	No
<b>4-6.3 Daylighting and Lighting Controls.</b>				
22.	Have one of the two strategies below been used to meet daylighting and lighting controls performance?			N/A
	<b>Strategy 1:</b> Demonstrated daylight factor achievement by calculation, modeling or measurement, or	Yes	IP	<input checked="" type="radio"/> No
	<b>Strategy 2:</b> Provision of occupant controlled lighting in required areas.	<input checked="" type="radio"/> Yes	IP	No
23.	Are automated lighting controls provided?	<input checked="" type="radio"/> Yes	IP	No
<b>4-6.4 Low-Emitting Materials</b>				
24.	Have low emitting materials been used for building modifications, maintenance, and cleaning?	<input checked="" type="radio"/> Yes	IP	No
<b>4-6.5 Integrated Pest Management.</b>				
25.	Is there DoD Component policy that requires an integrated pest management plan to minimize pesticide usage?	<input checked="" type="radio"/> Yes	IP	No
26.	Are EPA-registered pesticides used only when needed?	<input checked="" type="radio"/> Yes	IP	No
<b>4-6.6 Environmental Tobacco Smoke Control.</b>				
27.	Is smoking prohibited within the building and within 25 feet (7.62 meters) of all building entrances, operable windows, and building ventilation intakes?	<input checked="" type="radio"/> Yes	IP	No
<b>4-7 REDUCE ENVIRONMENTAL IMPACT OF MATERIALS.</b>				
<b>4-7.1 Environmentally Preferable Products.</b>				
28.	Are environmentally preferable products used for building modifications, operations and maintenance, and cleaning?	<input checked="" type="radio"/> Yes	IP	No
<b>4-7.2 Recycled Content.</b>				
29.	Do you have policy/specifications requiring products to meet or exceed EPA's Recycled Content recommendations for all building repairs/modifications?	Yes	IP	<input checked="" type="radio"/> No

Figure L-1. (Cont'd).

4-7.3 Biologically-Based Products.				
30.	Have products composed of the highest percentage of biobased content been used for building modifications, operations and maintenance, and cleaning where products meet performance requirements and are available at a reasonable cost?	Yes	IP	No
31.	Has a preference been given to purchasing products with the highest biobased content in solicitations for building modifications, operations and maintenance, and cleaning?	Yes	IP	No
32.	Are certified sustainable wood products used where products meet performance requirements and are available at a reasonable cost?	Yes	IP	No
4-7.4 Waste and Materials Management.				
33.	Are building occupants provided recycling services for paper, corrugated cardboard, glass, plastics, and metals, at a minimum, where markets or on-site recycling exist?	Yes	IP	No
34.	Are salvage, reuse and recycling services for waste generated from building operations, maintenance, repair and minor renovations, provided where markets or on-site recycling exist?	Yes	IP	No
4-7.5 Ozone Depleting Substances.				
35.	Has the use of ozone depleting substances (ODS) been eliminated where acceptable substitutes have been found?	Yes	IP	No

**Key:**

UFC Section	UFC Subsection	Response not required
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4-7 REDUCE ENVIRONMENTAL IMPACT OF MATERIALS.				
4-7.4 Waste and Materials Management.				
31.	Are building occupants provided recycling services for paper, corrugated cardboard, glass, plastics, and metals, at a minimum, where markets or on-	Yes	IP	No
Water Used for Heating and Cooling				
16.	Have lifecycle cost effective water conservation measures been deployed when potable water is used to improve the building's energy efficiency per the <i>Energy Policy Act of 2005</i> (EPAct 2005) section 109?	Yes	IP	No

Building level question      Global/Installation/Policy question

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